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Characterization of Water Quality in the Water Corridor Units of the Big Thicket National Preserve

Report prepared by

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Department of Ecology and Evolutionary Biology

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Under Cooperative Agreement with

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Mr. Richard Peterson, Superintendent

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EXECUTIVE SUMMARY

Monitoring and assessing the water quality of the streams and rivers within the Big Thicket National Preserve (BTNP) is an important component of management. External forces and actions by neighbors can affect both the ecological functioning and the aesthetic value of the Preserve by altering water quality. In this report we: 1) review existing data on water quality within the Preserve, including data collected by Preserve staff and data collected by external agencies and entities; 2) summarize normal patterns of key parameters and to compare these to similar rivers and streams in the coastal plain; 3) identify previously documented water quality problems within the Preserve; 4) examine existing data for long-term trends; and 5) attempt to identify data gaps within the current sampling regime.

As compared to the other rivers of Texas, the Neches River had excellent water quality, with lower ion concentrations (especially bicarbonate and calcium), lower hardness and lower specific conductance, lower pH, and the lowest total dissolved solids of all the rivers. Compared to other streams in the Gulf coastal plain to the east, the Neches was among the largest, but all its parameters fell within the what is apparently the normal range.

Seasonal patterns for selected parameters were analyzed for BTNP stations and USGS stations. Discharge tended to be both greater and more variable in the spring, while it was lower and less variable in the summer months. Dissolved oxygen was highest in winter and lowest in summer, with the majority of this variation was related to water temperature. There was no clear seasonal pattern of variation in pH or specific conductance, but alkalinity seemed to peak in late summer for several locations. Seasonal patterns for TDS were not strong, but were probably related to discharge.

Stations along the same watercourse were generally similar in the location and spread of their distributions of measured water quality parameters. Variations among streams were consistent with previously collected data. Among stations on a single stream, those along Little Pine Island Bayou showed the greatest variation in several parameters, indicating a radical change in character moving downstream.

Indications are that regional water quality declined over the decade. The most significant long-term trend was the region-wide decline in dissolved oxygen. There was weaker evidence for

a region-wide increase in water temperature. There was mixed evidence for an increase in organic loadings: TSS and color increased, but not significantly, while turbidity declined significantly. pH also increased regionally. Sulfates increased, while chlorides declined, probably due to declining releases of oilfield brines. The regional decline in dissolved oxygen is particularly troubling, as is the increase in pH. However, certain contradictions in the structure of the regional trends are also troubling and we have no ready explanation for certain apparent contradictions within the dataset. A change in sampling instrumentation and protocol may explain at least some of the regional trends.

The current basinwide assessments prepared for the State of Texas (Plummer et al., 1994) were reviewed for water quality problems. Current areas of concern for the Neches River include cadmium and zinc levels, dioxin contamination of fish tissues and saltwater intrusion. For Pine Island Bayou, chloride and DO concentrations and fecal coliform were carried forward as continuing concerns, and phosphorus loadings were identified as a new problem. For Village Creek, fecal coliform and pH were identified as problem areas. Aluminum concentrations were identified as a new problem, although the report suggested that high concentrations might be natural.

Based on BTNP data, low dissolved oxygen was a regional problem. Most of the pH excursions were for low pH (BC and JG sites), although some were for high values. Overall, the Little Pine Island Bayou watershed had the worst water quality in the region throughout its reach. Identified problems included DO, fecal coliform, sulfate concentrations, chloride concentrations and TDS. Turkey Creek also had some problems with fecal coliform, and the upper Neches sites had high TDS. The water quality sampling program of the BTNP has been very comprehensive and the effort is commendable. Frequency of sampling was adequate to detect potential problems and the data are superior to all other known datasets in this respect. Spatial coverage was also adequate and superior to all other sources, although BTNP should consider more stations on Village Creek. Sampling at the Neches River stations should be reinstituted and frequency should be increased to monthly to allow comparisons to all other stations. BTNP should also consider whether to refocus the sampling program so that the water corridors can be better characterized. The major problems with the BTNP program involve issues of quality control, data management,

and documentation. To increase the usefulness of the data, a QA/QC program should be designed and implemented for the water quality sampling program.

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INTRODUCTION

The Big Thicket National Preserve (BTNP) has several stream and river corridor units within its boundaries. The Water Corridor Management Plan is being prepared to assist park managers in making management decisions which directly affect these corridors. One issue of great importance is the water quality of the streams and rivers within the Preserve. Water quality of streams flowing through the Preserve is one way that external forces and actions can affect both the ecological functioning and the aesthetic value of the Preserve. The purposes of this report are: 1) to review existing data on water quality within the Preserve, including data collected by Preserve staff and data collected by external agencies and entities, 2) to summarize normal patterns of key parameters and to compare these to similar rivers and streams in the coastal plain, 3) to highlight previously documented water quality problems within the Preserve, 4) to examine existing data for long-term trends, and 5) to identify data gaps within the current sampling regime.

The scope of this report includes review and analysis of existing data collected by the Preserve staff and by the USGS. It also includes brief reviews of reports prepared by others, including those describing the body of research carried out under contract to the National Park Service (NPS) by Dr. Richard Harrel of Lamar University in Beaumont and his students. For identification of problems, we rely heavily on the regional assessments of water quality prepared in 1992 by the Lower Neches Valley Authority in cooperation with the Texas Water Commission (now the Texas Natural Resources Conservation Commission -TNRCC) under the authorization of the Clean Water Act (the so-called SB-818 report). This report summarizes, analyzes and interprets those data primarily as an aid to identification of issues and problems related to water quality within the Preserve. A number of physicochemical parameters are commonly sampled in water quality studies. These are listed in Table 1 along with their abbreviations.

Description of the Study Area

The study was conducted in the Big Thicket area of southeastern Texas (Marks and Harcombe, 1981), which is at the western edge of the Southern Mixed Hardwoods region (Kuchler, 1964). The Big Thicket is located on the Gulf Coastal Plain, bounded

Table 1. Abbreviations for water quality parameters

Abbreviation	Parameter
Temp	water temperature
DO	dissolved oxygen
$\%O_2$	oxygen, percent saturation
BOD	biochemical oxygen demand
CO2	carbon dioxide
alk	alkalinity
pH	pH, acidity
spec. cond.	specific conductance
cond.	conductivity
TOC	total organic carbon
Cl	chlorides
turb.	turbidity
app. color	apparent color
PO_4	orthophosphates
NH_4	ammonia nitrogen
Fe, tot.	total iron
TSS	total suspended solids
TDS	total dissolved solids
TDO	total dissolved organic solids
TDI	total dissolved inorganic solids
chloro.	chlorophyll "a"
disch.	discharge

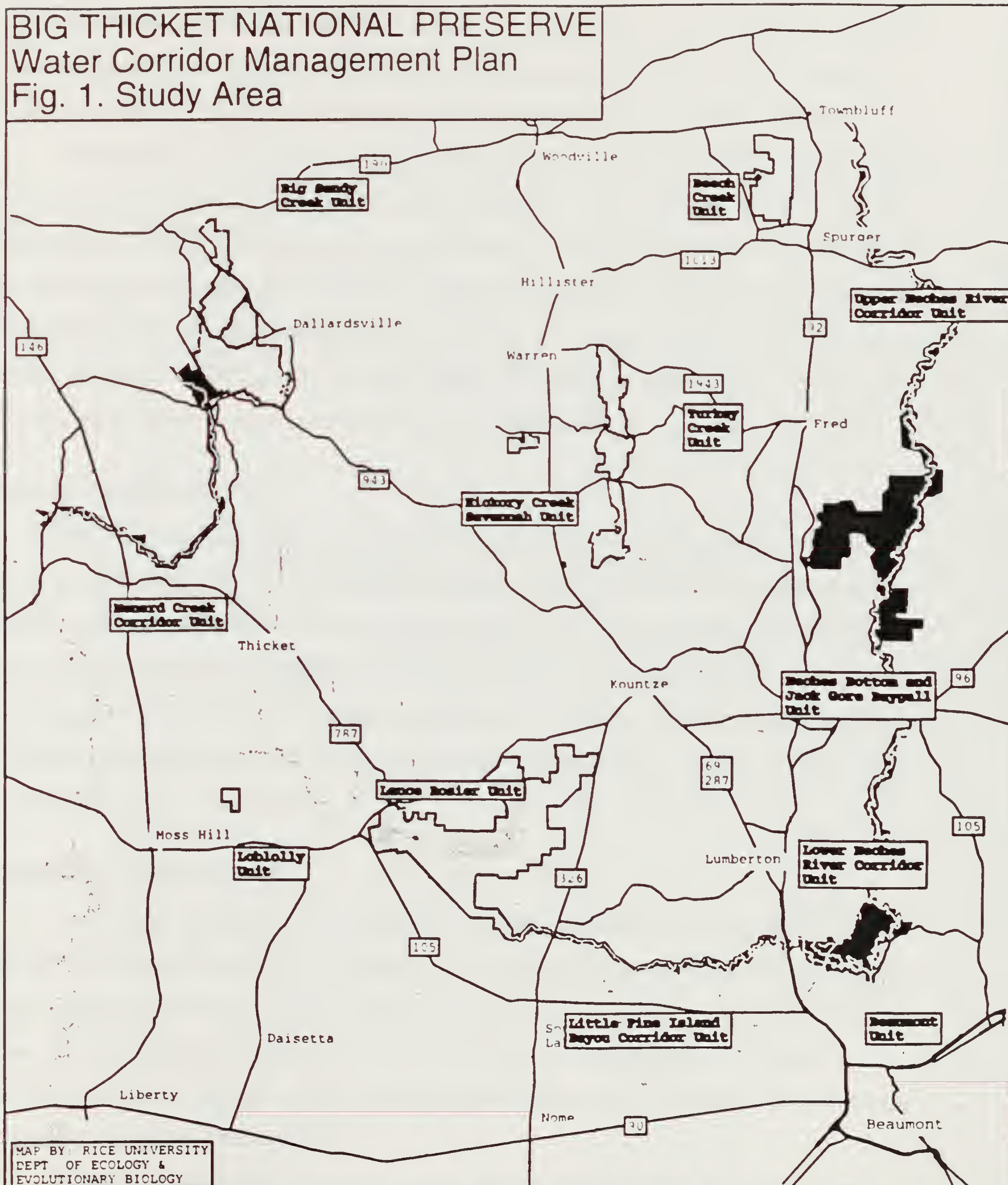
approximately by the Trinity River on the west and the Sabine River on the east. The BTNP is comprised of twelve units (Fig. 1), six of which are defined for management purposes as water corridors: Menard Creek Corridor Unit, Little Pine Island Bayou Corridor Unit, Upper Neches River Corridor Unit, Neches Bottom and Jack Gore Baygall Unit, Lower Neches River Corridor Unit, and the Beaumont Unit. Other streams flow through units of the Preserve, including Big Sandy Creek, Turkey Creek, and Beech Creek, but it is the six Corridor units on which we focus here (corridor units are black on Fig. 1; other units in grey). Hydrologically, all streams within the Preserve are part of the Neches River watershed, except for the Menard Creek Corridor Unit, which is within the Trinity River watershed.

Coastal Plain Rivers of the Southeastern United States

The Atlantic and Gulf of Mexico Coastal Plain of North America is a physiographic province (4800 km long by an average of 400 km wide) which extends from Massachusetts to Tampico, Mexico, covering approximately 10% of the continental U.S. (Isphording & Fitzpatrick 1992). Excluding the Mississippi, Rio Grande, and Mobile Rivers, most rivers in the Coastal Plain lie almost wholly within the province. Rivers with headwaters in the Piedmont include the Savanna (GA), Cape Fear (NC), Roanoke (NC), Potomac (VA), Susquehanna (MD), and Delaware (PE).

Although the diversity and complexity of the streams in the Gulf Coast Plain make generalizations difficult, they are categorized as "warmwater" streams which tend to have : (1) low gradients, (2) moderate to high discharge, (3) low turbulence, and (4) rubble-sand-mud substrates. There are strong seasonal variations of many properties of these streams which are related to the amount of runoff. Characteristically, there are distinct wet and dry seasons with lowest flow from August to October and highest flow from January to March (Felley 1992).

Streams of the Gulf Coastal Plain tend to be extremely low in dissolved solids, pH, conductivity, and hardness (Felley 1992). Oxygen levels tend to be relatively high, normally not dropping below 70% saturation. Oxygen depletion can occur in low-order streams during periods of low flow, in streams contaminated with municipal or industrial pollution, or in spring-fed streams. Conductivity and pH levels are lower in the wet season and higher in the dry season.



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Nitrate concentrations are higher in the wet season, presumably from run-off, and lower in the dry season, indicating higher primary productivity which removes nitrates from the water column. Phosphate levels are low year-round, with no apparent seasonal variation (Felley 1992).

Compared to the other rivers of Texas, the Neches River had excellent water quality, with lower ion concentrations (especially bicarbonate and calcium), lower hardness and lower specific conductance (Table 2). The Neches also had a generally lower pH, due to its parent material and the input of organic matter. The Neches also contained the lowest total dissolved solids of all the rivers, and yielded a relatively large amount of discharge per unit area. Compared to other streams in the Gulf coastal plain to the east (Table 3), the Neches was among the largest, but all its parameters fell within the what is apparently the normal range.

Plants of Coastal Plain Rivers

The most important primary producers for these streams are terrestrial and emergent plants of stream edges and the surrounding floodplains. Detritus from these essentially terrestrial sources is the principal source of food for aquatic heterotrophs. Primary production within the stream comes from algae and aufwuchs (aquatic plants attached or clinging to stems or leaves of rooted aquatics or to snags or other stationary objects) (Felley 1992). Gross primary production (GPP) of second order streams in this province is from 2-12 g /m^2 day^{-1}. This accounts for only 1/4-1/2 of total respiration in the stream.

Animals of Coastal Plain Rivers

Invertebrate biomass varies considerable among streams, habitats and seasons. The most productive habitats are those with vegetation or fine sand/mud substrates with detritus (standing crop of 50-60 g/m^2, wet wt.). Sand substrates with litter are less productive (21.0 g/m^2) and have fewer species. Bare sand substrates have the least biomass and fewest species. Sand and sand/litter habitats are the most typical of small streams in the Gulf Coastal Plain from the Florida panhandle to Louisiana (Felley 1992).

Invertebrate production on snags or woody debris is very important for southeastern streams; the snags act as an important habitat for macroinvertebrates which, in turn, are a

Table 2. Selected physicochemical characteristics of western Gulf slope rivers (from Table 12.2 in Conner and Suttkus, 1986).

	Nueces	San Antonio	Guadalupe	Colorado	Brazos	San Jacinto	Trinity	Neches	Sabine
Drainage Area (km 2)	43253	10619	15540	107226	116550	10360	46620	25900	25123
Discharge (m3/km2)	0.0003	0.0011	0.0033	0.0006	0.0022	0.0058	0.0056	0.0046	0.0088
Ion Concentrations (Mg/l)									
Silica	19	17	11	8.3	8.3	19	10	12	12
Calcium	56	86	61	50.1	61	31	42	9.7	9.5
Magnesium	5.9	17	14	13	10	3.2	4.2	3.1	3
Sodium	35	76	26	25	56	27	60	18	30
Bicarbonate	207	254	223	180	170	88	123	32	32
Sulfate	24	88	28	37	61	9.1	45	15	15
Chloride	33	101	36	37	82	60	61	25	43
Nitrate	0.5	9.3	2.5	0.9	1.3	0.4	4.6	0.8	0.6
TDS	279	527	289	258	367	185	282	103	130
Hardness - Ca, Mg	160	284	208	178	194	91	124	37	36
Non-carbo Non-carbonate	0	76	26	30	55	19	23	11	10
Specific Conductance	474	904	513	469	658	329	503	170	237
pH - maximum	8.1	8.2	8.2	7.9	8	7.5	8.1	7.1	7.1
pH - minimum	7	7.2	6.9	6.8	6.8	6.3	6.7	5.7	5.6

Table 3. Annual Averages of Physicochemical Variables for Streams in the Gulf Coastal Plain
from Felley (1992), except Neches

Drainage	Area (km2)	Flow (m3/s)	Temp. (Celsius)	Conductivity µS/cm)	Diss. Oxygen (mg/L)	pH	Hardness (mg/l)	Phosphate (mg/L)
Neches	20,600	170.7	21	158	8.5	6.8	32.64	0.08
Calcasieu	4403	71.1	19	184	7.6	6.8	17.2	0.08
Amite	133	1.5	20	181	8.5	6.2	12.9	0.1
Tickfaw	247	6	18	219	8.4	6.4	13.7	0.11
Tangipahoa	1673	24	19	188	8.4	6.2	13.1	0.15
Perdido	2396	21.8	20	22	8.4	4.7	3.6	0.1
Escambia	10878	185.1	20	79	8.1	6.4	6.6	0.13
Blackwater	2227	30	18	25	9	5	6.6	NA
Yellow	3626	65	18	54	8.3	6.3	20.7	0.08
Choctawhatchee	12033	204.8	21	98	7.5	6.6	37.9	0.1
Ochlockonee	5957	45.7	20	121	7.5	6.1	25.8	0.64
Aucilla	2279	15.7	19	116	7.3	5.9	55.2	0.17
S. Withlacooche	5180	32	22	264	5.4	7.6	125.4	0.12
Hillsborough	1787	16.8	23	287	5.8	7.1	138.8	2.3
Peace	5957	32.7	22	316	7.8	6.9	117.6	8.3

NA = not available

significant food source for many fish species. Invertebrate trophic groupings vary spatially, reflecting stream order (Felley 1992). Upstream communities are dominated by collector/gatherers and scrapers, while predators (piercers and engulfers) increase downstream.

Invertebrate biomass varies seasonally and with stream size in Gulf Coastal streams. Small and medium-sized streams (orders 1-4) have biomass minima in the summer. Detritus entering streams, mostly during the wet season, is an important food source for invertebrates. Larger streams (orders 5-6) have biomass peaks in summer. This may be due to downstream consumers being more dependent on primary producers within the stream whose prime growing season would be spring and summer (Felley 1992).

Many of the important fish species of the Gulf Coastal Plain are widespread. There are few endemic freshwater fish in the medium to low gradient streams. In general, streams west of the Suwannee(GA-FL) drainage are primarily inhabited by minnows (*Cyprinidae*), sunfish (*Centrarchidae*), darters (*Percidae*), and suckers (*Catostomidae*). Predatory fish are not as important numerically, but comprise a larger fraction of total biomass. The most important predatory species are the spotted gar (*Lepisosteus oculatus*), bowfin (*Amia calva*), and largemouth and spotted bass (*Micropterus salmonoides* and *M. punctulatus*). Fish assemblages are ecologically differentiated with respect to stream order, current speeds, amounts of debris, cover, and vegetation (Felley 1992). There are also seasonal differences in habitat use by different fish species. In the dry season, many fish species tend to be more restricted in habitat usage, depending more heavily on detritus as a food source. During the wet season, most species are found in a much wider variety of habitats and several forage heavily in flooded areas. The reproductive success of several species is correlated to the amount of flooding. Fish productivity, in general, corresponds to invertebrate productivity (Felley 1992).

Characterization of Blackwater Rivers

Because blackwater rivers are an important subset of coastal plain rivers which share certain similarities with the Neches River, a separate description of them is included here. Except when noted, the following description is taken from a general characterization of blackwater rivers on the coastal plains of the southeastern U.S. (Meyer, 1992).

Blackwater streams have a high total organic carbon (TOC) content which varies with flow conditions (highest when the river is in flood and lowest during periods of low discharge). Most of the TOC is in dissolved organics (DOC >96% of TOC). However, the particulate portion is an important food source for an abundant, filter-feeding macroinvertebrate community. In the southeastern U.S., blackwater streams drain broad areas of low relief and have extensive floodplains which are flooded annually. High DOC concentrations cause the dark color and high acidity of the water. Acidity tends to decrease as stream size increases (Smock and Galinsky 1992).

Another distinguishing characteristic of blackwater streams is the ratio of dissolved inorganic to organic constituents. Most rivers worldwide have a ratio of 10:1 (inorganics:organics). In blackwater streams of the southeastern U.S., the ratio is 1:1. The dissolved organics (mostly humic and fulvic acids leached from swamp soils) lower pH and are responsible for the acidic conditions. Although blackwater streams are generally acidic, pH varies widely (Smock and Galinsky 1992). It can be affected by groundwater supply and the type of area it drains. Calcium-rich springs can produce neutral-to-slightly-alkaline conditions. Streams that drain mineral soils, as opposed to peat (swamps, bogs, or marshes), have lower DOC which means color and acidity are also lower while alkalinity, hardness, DO, cations and nutrients are higher. DOC, with marked seasonal changes, usually ranges from 5-50 mg/L (Smock and Galinsky 1992). In blackwater streams of the southeastern U.S., concentrations of dissolved solids, and hence conductivity (21-64 mS/cm), tend to increase from upper to lower coastal plains (Smock and Galinsky 1992). Blackwater rivers have low levels of dissolved oxygen (DO) during warm months, caused by high community respiration rates. The high respiration is sustained by organic input from extensive swampy areas in the surrounding floodplains as well as by organics produced by in-stream photosynthesis. For example, the Ogeechee River has moderate gross primary productivity (GPP) averaging 2.22 $g/m^2 \cdot day^{-1}$ and a community respiration rate of 6.7 $g/m^2 \cdot day^{-1}$.

The inorganic chemistry of blackwater streams also distinguishes them from other river types; it is regulated by sodium sulfate rather than calcium carbonate. This causes bicarbonate, a major ion in most streams, to occur in low concentrations and produces a low buffering capacity

(Smock and Galinsky 1992). Thus, blackwater rivers are characterized by relatively low alkalinity. Other important elements of water quality include nitrate and phosphorus (from fertilizer) and biocides. Concentrations of these chemicals are affected by agricultural run-off, so high concentrations coincide with periods of application.

Compared to several blackwater rivers (Table 4), the Neches had a low concentration of DOC, and a correspondingly lower DOC:TOC ratio than is thought to be characteristic of blackwater steams in general. The ratio in the Neches River of dissolved inorganics:organics was typical of world rivers (11.4:1 for the Neches compared to 10:1), and was much higher than expected for blackwater rivers. Still, as compared to other Texas rivers (Table 2), the Neches had much lower levels of dissolved inorganics, and was more similar to eastern coastal plain rivers in this respect. Turbidity for the Neches was much higher than for the Satilla, and was generally higher than expected for a blackwater river. Color was high for the Neches, but perhaps not as high as might be expected for a blackwater river. Overall, we conclude that the Neches was more similar to rivers of the eastern Gulf coastal plain than to western coastal plain rivers, but it probably would not be classified as a blackwater river.

Bottomland forests associated with blackwater streams are very productive with annual litterfall of 600-800 g organic matter/m^2. Dominant tree species in blackwater river floodplains include bald cypress (*Taxodium distichum*), sweetgum (*Liquidambar styraciflua*), water oak (*Quercus nigra*), swamp black gum (*Nyssa sylvatica* var. *biflora*), water tupelo (*Nyssa aquatica*), and willow (*Salix* sp.). There is much woody debris (snags) on banks and in channels which provides ideal habitat for the invertebrate population.

Filter-feeding macroinvertebrates are abundant, productive, and diverse in most southeastern blackwater rivers. A large portion of the seston (all bodies which swim or float in water) is living: 31% bacteria, 4% protozoa, 6% algae, and 0.2% drifting invertebrates. The bacteria apparently come from the floodplain rather than the channel. The fish community is abundant and diverse. Up to 55 species were found in fourth-order streams (64 spp. in 5 streams). In comparison, there are 87 species in the Lower Neches River Basin (Suttkus and Clemmer 1979 and Conner 1977), making the Neches comparatively high in diversity. From 50 to 70% of total fish standing stock biomass is usually game fish (Smock and Galinsky 1992).

Table 4. Water quality data for lower Neches River Basin and several blackwater rivers

Souces: Neches and Tributaries from USGS data, others from Meyer (1992) and Wharton and Brinson (1974).

Parameter	Annual Means (min.-max.)							
	Neches and Tributaries				Blackwater Rivers			
	Neches River	Village	Pine	Sabine	Tifton Plateau		Tallahassee Plateau	Pleistocene, GA
	Evadale	Creek	Island Bayou	River	Ogeechee	Canooche	Ochlockonee	Satilla
TOC (mg C/L))	10.5 (3.2-41)	NA	NA	NA	8.8	8 1	9	20
DOC (mg C/L)	7.3 (5.2-12)	NA	NA	NA	8.4	NA	NA	~20
DOC:TOC	0.7	NA	NA	NA	0 96	NA	NA	~1.0
Color (Pt-Co)	90 (20-240)	NA	NA	74 (41-127)	66.7	NA	NA	136.3
Dissolved Oxygen (mg/L)	8.5 (4.7-13.2)	NA	NA	6.8 (2.5-9.9)	7.4	NA	NA	6.9
pH, field	6.8 (5.9-8.2)	6.2 (4.8-7.6)	6 8 (5.8-7.8)	6 8 (6.4-8 3	6 5	5 6	7	4 9
Temperature (Celsius)	21 (6-32)	19 (4-36)	20.5	21 2 (12.3-31.6	17 8	NA	NA	19 1
Turbidity (JTU)	35 (15-150)	NA	NA	NA	NA	NA	NA	4.7 (2-7)
Specific Conductance (umhos/cm)	158 (67-235)	104 (31-237)	325 (32-11600)	NA	47-104	35-57	49-327	45 (28-63)
Discharge (m3/s)	132.7 (1.1-677)	20.0 (0.73-164)	8.1 (0.06-73.6)	192.3 (5.3-1711	115	NA	NA	77
Hardness (Ca,Mg mg/L)	32.6 (14.3-53.9	17.54 (7-26.2)	51.26 (10-577)	NA	12-28	6-11	11-56	5 2
Bicarbonate (mg/L)	19.5 (14-26)	NA	NA	NA	NA	NA	NA	11 (7-20)
Total nitrite+nitrate (mg/L)	0.09	NA	NA	NA	<0.18	<0 08	<0 17	<0 06
Total phosphorus (mg/L)	0.06 (0 01-0.2)	NA	NA	NA	NA	NA	NA	NA
Dissolved Solids (mg/L)	90.6 (35-132.4)	NA	NA	NA	NA	NA	NA	NA
Diss. Inorganics:Organics	11.4 : 1	NA	NA	NA	NA	NA	NA	0 042361111
Dissolved Fe (mg/L)	200 (10-920)	NA	NA	NA	NA	NA	NA	NA
Drainage basin area (km2)	20600	NA	NA	NA	13500	NA	NA	10200

Review of Regulatory Framework for Water Quality Protection in Texas

Water quality protection in Texas is charged to several state and federal agencies. Discharges into waterways are regulated principally through two kinds of permits: 1) permits issued by the Texas Natural Resource Conservation Commission (TNRCC) as authorized by the Texas Water Code §5.103 and §26.023, and 2) permits issued by the U. S. Environmental Protection Agency (EPA) authorized under the National Pollutant Discharge Elimination System (NPDES) provisions of the federal Clean Water Act §402 (33 United States Code 1342). State regulations containing descriptions of standards, general criteria, and site-specific designated uses and basin or site-specific criteria can be found in the Texas Administrative Code, Title 30, Environmental Quality, §307, Texas Surface Water Quality Standards. Permits for discharge from oil and gas activities are regulated separately (see below).

The dual permitting requirement exists because EPA has not delegated authority to administer the NPDES program to Texas, as it has in most other states. In practice, the process and permit requirements are similar, with the federal program requiring more citizen participation. Both processes provide public notice and allow the opportunity for affected parties to comment. Both agencies also maintain mailing lists for parties interested in particular geographic areas and route notices of all permit applications accordingly.

The Texas Railroad Commission (RRC) and the State Soil and Water Conservation Board (SSWCB) also have roles in water quality protection. The RRC is responsible for issuing state discharge permits for oil and gas activities. The regulations covering issuance of those permits can be found in the Texas Administrative Code at Title 16, Economic Regulation, §3.8, Water Protection. In general, the regulations prohibit the discharge of any material which would alter the physical, thermal, chemical, or biological quality of surface or subsurface waters that would render the water harmful, detrimental, or injurious to humans, animal life, vegetation, or property, public health, or enjoyment. However, the regulations enumerate many specific types of disposal of oil and gas wastes (primarily landfarming, but some forms of discharge directly to surface waters) as being allowed without a permit. Notice of the permit application for pits requiring permits is limited to the surface owners, and the city clerk, if the property is inside an incorporated area. For discharge into a watercourse other than the Gulf of Mexico or a bay, the

applicant must also give notice to the surface owners of each waterfront tract within 1/2 mile downstream.

The SSWCB oversees a voluntary program for abatement of agricultural and silvicultural nonpoint source pollution through the identification of problem areas by the state board or a local soil and water conservation district and the subsequent development of water quality management plans by the local soil and water conservation districts. The regulations may be found in the Texas Administrative Code, Title 31, Natural Resources and Conservation §523, Agricultural and Silvicultural Water Quality Management.

Review of Previous Work

Harrel and Watson (1975) summarized existing data on water quality within the area encompassed by the BTNP, identified water quality problems, and developed recommendations on future research. Many of the potential problems identified by the authors are still faced by NPS in the stream corridors. These include 1) the effects of lumbering and wood production on neighboring lands, including increased erosion and siltation after harvest, and pollution by biocides used to control unwanted vegetation or insects, 2) the effects of road-building on drainage patterns, 3) the effects of oil and gas exploration and production, including pollution from older fields by brine and petroleum products, 4) the effects of development and construction on neighboring property, including erosion, siltation, and pollution from septic tanks entering the Preserve via the water table, 5) saltwater intrusion from the Neches River, and 6) edge effects of all neighboring land-use practices on corridors due their narrowness.

Harrel (1976) undertook a preliminary limnological survey of streams in the Preserve to : (1) determine locations for establishment of water quality monitoring stations, (2) obtain baseline water quality data, (3) locate potential sites of pollution, and (4) make recommendations for management and future studies. Water quality samples were taken only once (during flood), so the data were considered preliminary. Streams generally had low pH, cond., and alk. and moderate-to-high CO_2, NO_3, PO_4, and turbidity. Little Pine Island Bayou, which has a clay substrate, was more turbid than the other streams. It also received more sewage pollution.

Harrel (1977) reported the results of an ensuing study of physicochemical properties measured in the Lance Rosier, Big Sandy Creek, Menard Creek, Turkey Creek, and Beech Creek

Units from 5/5/76-12/22/76. The purpose of the study was to provide a baseline for water quality parameters against which to evaluate the impacts of future activities such as development in the watershed outside the Preserve, increased use of park facilities, and industrial or timber activities. Physicochemical parameters were sampled monthly and benthic macroinvertebrates were sampled bimonthly. Harrel found an influx of oil field brine into Little Pine Island Bayou during July-Aug. which increased spec. cond., Cl, pH, TDS and decreased turbidity and color. For Menard Creek, all parameters were found to be within expected normal ranges for comparable local streams, although there was a trend toward increased alkalinity, pH, spec. cond., Cl, and TDS as the channel cut into more calcareous substrate near the Trinity River. In this watershed, a heavily developed area, Big Thicket Lake Estates, was identified as being served entirely by septic tanks. Harrel recommended that it be monitored for fecal contamination.

Kost (1977) surveyed physicochemical conditions from May 1976 to April 1977 in the Beech Creek Unit. Overall water quality was good, but values were strongly influenced by seasonal parameters such as discharge and temperature. Turb. , cond., and TDS were low despite lumbering activities inside and outside the unit. The macrobenthic community structure was highly diverse (172 taxa and 21,766 individuals collected). Dominant species included chironomids (*Cladotanytarsus* sp., *Polypedilum* sp., & *Calopsectra* sp.), the oligochaete *Limnodrilus hoffmeisteri*, and the clam *Sphaerium* sp. Lack of discharge at two stations from August to October caused reductions in the number of taxa, individuals, and species diversity.

Harrel and Darville (1978) surveyed physicochemical conditions and macrobenthos in streams of the Lance Rosier, Little Pine Island Bayou, Beech Creek, Turkey Creek, Big Sandy Creek, and Menard Creek Units from July 1977 to August 1978. In Little Pine Island Bayou, percent oxygen saturation varied from 12-100%, with the lowest values at low or no discharge in small isolated pools. BOD was relatively low at all times (<10.4 ppm). CO_2 generally decreased downstream and varied from 18.5 ppm (May) to 3 ppm (July-Aug.). Alkalinity indicated some influx of oilfield brine and sewage effluent (Pinewoods Estates). High conductivity (20-3550 umhos/cm) and chloride concentrations (28-1440 ppm) were attributed to oilfield brine from the Saratoga and Sour Lake oil fields and sewage effluent (Pinewoods Estates). Turbidity varied from 20 JTU (in Nov. during low flow) to 395 JTU (in Dec. during high flow).

During normal discharge, the station at Bevil Oaks, a downstream location, had the highest turbidity, TSS, and TDS. In general, Little Pine Island Bayou had low values of turbidity, TSS and TDS above the confluence with Pine Island Bayou and high values below it. Turbidity was always lowest at the station near Sour Lake, which Harrel attributed to contamination with brine, which can precipitate suspended particles.

Fecal coliform varied from 0- 5880/100ml (after heavy rain). The station below Pinewood Estates had no or little fecal coliform except after a heavy rain. Benthic macroinvertebrates included 123 taxa (15,263 individuals collected). Dominant groups were oligochaetes (62%, 23 species), chironomids (22.5%, 31 species), gastropods (3.6%, 4 species), and amphipods (3%, 3 species). The dominant organism was the oligochaete, *Limnodrilus hoffmeisteri* (47% of individuals). Highest densities occurred in April. Heavy rains and flooding were found to reduce population densities of benthic invertebrates.

Physicochemical and fecal bacteriological data were also collected in the Beech Creek, Turkey Creek, Big Sandy Creek and Menard Creek Units. All were sampled during periods of low flow (channel is 1/2 bank full) except for Big Sandy in August, which had intermediate flow (>1/2 bank full, but still within the channel). Low DO only occurred in Beech Creek and only under conditions of low or no discharge. BOD values were within the expected range. CO_2 concentrations of >10 ppm (limiting to some aquatic populations) were observed at 4 stations in Beech Creek and once in Big Sandy. All streams had low alkalinity, with bicarbonate being the only source. All streams had low conductance and low concentrations of chlorides. Turbidity and color were normal for area streams. Orthophosphates were low (<1 ppm). NH_4 occurred in limiting concentrations only in isolated pools. All streams had Fe concentrations >1 ppm which is the taste threshold. TSS and TDS concentrations were low to normal for area sand and substrate streams. Chlorophyll 'a' occurred in low concentrations as would be expected in flowing, shaded streams. The fecal bacteria:fecal streptococcus ratio indicated sewage contamination at 3 stations in Menard Creek.

Harrel and Bass (1979) conducted a physicochemical and macrobenthic study of water quality in Menard creek from July 1978 to June 1979. Physicochemical conditions generally indicated good water quality. DO concentrations were always high and other parameters were

within expected ranges. Conductivity and Cl concentrations indicated low levels of oil field brine at two stations. Fecal bacteria were higher than acceptable at all stations throughout most of the study period; highest concentrations corresponded to heavy rains. Fecal coliform : fecal streptococcus ratios indicated sewage contamination in 12% of the samples. The macrobenthic community included 125 taxa (7,462 individuals collected). Chironomids (44.8%, 38 spp.) and oligochaetes (32.1%, 13 spp.), had the highest diversity.

Harrel and Commander (1980) surveyed streams of the Turkey Creek Unit from August 1979 to June 1980. Physicochemical conditions, in general, were excellent. High Cl concentrations in Village Creek during April were probably due to oilfield brine. This period also showed lowered levels of diversity in the macrobenthic community. Oxygen saturation was >79% throughout the year, indicating excellent water quality. Bicarbonate alkalinity, pH, and CO_2 were low at all stations, a normal condition for tannic acid-laden streams. Turbidity, apparent color, TSS, and TDS fluctuated with discharge levels which ranged from 0.5 m^3/s (July) to 33.3 m^3/s (March).

There were 5 permitted waste discharges in the watershed upstream from the unit, all treated domestic wastewater. Bacterial contamination of streams was slight with no evident trends. Macrobenthic community structure included 134 taxa with the oligochaete, *Limnodrilus hoffmeisteri*, dominant (34-70%) at all locations. Diversity values (d), ranged from 1.31 (Feb.) - 44 (Oct.). The number of individuals generally increased with discharge.

Harrel and Newberry (1981) monitored physicochemical parameters, bacteria, and macrobenthos in Big Sandy Creek from September 1980 to August 1991. Physicochemical conditions indicated good water quality, with extremes corresponding to discharge levels. All parameters were within ranges expected for clean water streams in southeastern Texas. Bacterial contamination was slight and the stream met the criteria for contact recreation. The macrobenthic community included 171 taxa (4076 individuals collected). Dominant species were *Tanytarsus* sp. (13.3%), *Palpomyia* sp. (9%), and *Limnodrilus hoffmeisteri* (8.7%). Diversity values (d) ranged from 2.5-4.6. Annual diversity was high for all stations indicating very little stress on the benthic fauna.

In 1984, the Lower Neches Valley Authority (LNVA) commissioned a study of Pine

Island Bayou which presented recommendations about management practices (Lower Neches Valley Authority & Alan Plummer & Associates, Inc., 1984). The recommendations were based on an intensive sampling program performed on Pine Island Bayou by the LNVA to characterize nonpoint source loads in the Pine Island Bayou watershed. They concluded that: 1) DO levels were not a significant problem in Pine Island Bayou or its tributaries; 2) nonpoint sources frequently caused fecal coliform levels to exceed the 200/100ml criterion; 3) oil field areas had a significant impact on chloride concentrations in lower Pine Island Bayou but stream standards for chlorides were being met.

Recommendations included the following: 1) implement public information program for residents in affected counties about problems associated with improper disposal of sewage, 2) perform short-term monitoring on bacteriological pollution on a small scale, 3) develop criteria for alternative on-site sewage disposal systems, 4) establish regulations for private sewage systems in Hardin county, while continuing to enforce existing regulations in Jefferson and Liberty counties, 5) monitor population growth periodically to determine economic feasibility of public wastewater treatment system, and 6) perform ongoing water quality monitoring to determine success of the above measures.

Recommendations for addressing the problem of saltwater (brine) pollution in Pine Island Bayou watershed included : 1) identify sources of saltwater pollution in Saratoga, Batson , and Sour Lake oil fields, 2) characterize particular problems associated with each pollution source and determine feasibility of controls, 3) if controls are feasible, prioritize and determine responsibility for implementing controls, 4) have responsible parties evaluate, design, and implement controls, and 5) conduct routine water quality monitoring in Pine Island Bayou watershed to assess effectiveness of control measures.

Hughes *et al.* (1987) summarized the first two years of data collected in the National Park Service's water quality monitoring program (11/84-11/86) and compared it to earlier studies and monitoring activities. Beech Creek, Black Creek and Big Sandy Creek had maximum temperatures between 6-30°C, and DO generally > 5 mg/L with occasional DO<4 thought to be naturally occurring in pristine streams as the result of high temperature, low flow and natural organic loading. pH was found to be within the expected range, with readings being slightly

more acidic in Beech Creek and Black Creek. Specific conductance was generally low (46 mmhos/cm at Beech Creek, 85 mmhos/cm at Big Sandy, 179mmhos/cm. at Black Creek , the highest), with most sites having a maximum of less than 110 mmhos/cm., indicating little human impact. There were no unusually high values for turbidity. Bacterial counts were not excessive (mean = 200 fecal coliform/199 mL), but were somewhat elevated.

Little Pine Island Bayou, Pine Island Bayou and Menard Creek also had maximum temperatures averaging, 6-30°C. DO was frequently low in Little Pine Island Bayou (min 0.3 mg/L), while in Menard Creek, DO stayed within acceptable levels (always >6.0 mg/L). pH was naturally slightly acidic (5.4-7.7 at Little Pine Island Bayou, and 5.9-7.0 at Menard Creek). Specific conductance was often high in both Little Pine Island Bayou and Pine Island Bayou throughout the period of sampling. In July 1985, an oilfield brine spill caused by a pipeline rupture resulted in exceedingly high specific conductance readings (16,241 mmhos/cm) in Little Pine Island Bayou. The effects of the spill lasted for more than 26 months (the length of the study). The brine finally settled to the bottom, reducing the specific conductance at the surface to about 2000 mmhos/cm. Menard Creek had much lower specific conductance (means ranged from 27-111 mhos/cm).

Turbidity was low for all these streams, while chlorides were less than 100 mg/L, except after the brine spill. Chlorides in Little Pine Island Bayou after the spill reached a maximum of at least 1,400 mg/L, while Menard Creek never ranged above 25 mg/L. For bacterial counts, there was considerable fluctuation of fecal coliform concentrations, but averages were reasonable. All other parameters were within expected limits.

The Neches River from Steinhagen Reservoir to Beaumont had generally good water quality which met the state and federal standards for high quality aquatic habitat and contact recreation. Neches River temperatures ranged from 8-30° C, and DO was always in excess of 7.5 mg/L. The median pH was 6.6 and the range was 6.2-7.8. Chloride values were all below 50 mg/L, and specific conductance ranged from 109-173, with a median of 154mmhos/cm. Turbidity was low (all values < 40 NTU), and fecal coliform averaged only 47/ 100mL. Because of the short record and differences in instrumentation, no trend analysis was conducted.

Wells and Bourdon (1985) conducted a statistical and trend analyses of USGS water

quality data from the Lower Neches River basin (Neches River at Evadale, Village Creek, and Little Pine Island Bayou) to document baseline water quality conditions in stream segments that flow through BTNP. They found that TDS concentrations were low, <132 mg/L in 50% of samples. DO in the Neches River at Evadale was generally high, with a median of over 8 mg/L. Total N (< 1.8 mg/L) and total P (< 0.2 mg/L) concentrations were low. Trend tests for TDS and major ions suggested small downward trends in total alkalinity, Ca, and hardness in the Neches River at Evadale and Pine Island Bayou near Sour Lake. Small upward trends in sulfate concentrations were detected at all stations.

Finally, in 1992 a regional assessment of water quality for the entire lower Neches River Basin was undertaken (Alan Plummer and Associates, 1992). This report identified and examined all sources of water quality data, identified potential problems for each segment, and summarized this information in an accessible and compact form. In addition, tabular material identified all permitted diversions, all permitted municipal and industrial wastewater disposal sites, all permitted solid waste management facilities, and unauthorized dumps and Superfund sites. A more detailed treatment of this report will be found in later sections of this report.

GENERAL DESCRIPTION OF LOCAL WATER QUALITY PATTERNS

The purpose of this chapter is to review and analyze existing water quality monitoring data collected by the Preserve staff on streams within the Preserve, and by the USGS on major streams within the Big Thicket Area. In particular, we describe patterns of seasonal variation, as well as local and regional patterns and long-term trends.

Description of Big Thicket National Preserve Sampling Program

At the request of BTNP Resource Management staff, the Water Resources Division of the National Park Service designed and implemented a water quality monitoring program for the Big Thicket National Preserve (Flora, 1984). The report identified potential sources of water pollution including: 1) oil field activities both within the Preserve and on neighboring land (erosion, biocides, oil spills, brines), 2) timber operations on neighboring property (erosion, pesticides, herbicides), 3) sewage treatment plant effluent, 4) herbicides and pesticides applied on neighboring lands.

NPS

Streams were classified into one of three categories based on historic water quality, streamside land uses, and susceptibility to degradation. Water quality parameters which were measured include temp., spec. cond., turb., pH, DO, stage (water level), alkalinity, chloride, sulfate, color, TDS, TSS, oil and grease, fecal coliform, and fecal streptococcus. Category 1 streams had the best water quality in BTNP and had the highest priority for protection. They were Big Sandy Creek, Beech Creek, Turkey Creek, Village Creek, and Black Creek. Category 2 streams had degraded water quality for 1 or 2 parameters. They were Little Pine Island Bayou, Pine Island Bayou, and Menard Creek. These streams had more permitted point source discharges of sewage effluent than Category 1 streams and the BTNP judged that it had less control over factors affecting their quality. Two of these streams are among the water corridors which are the focus of this report: Little Pine Island Bayou and Menard Creek. Category 3 streams were those for which the BTNP had little control over water quality. Category 3 contained the Neches River from Steinhagen Reservoir to Beaumont, encompassing four of the six water corridors which are the focus of this report.

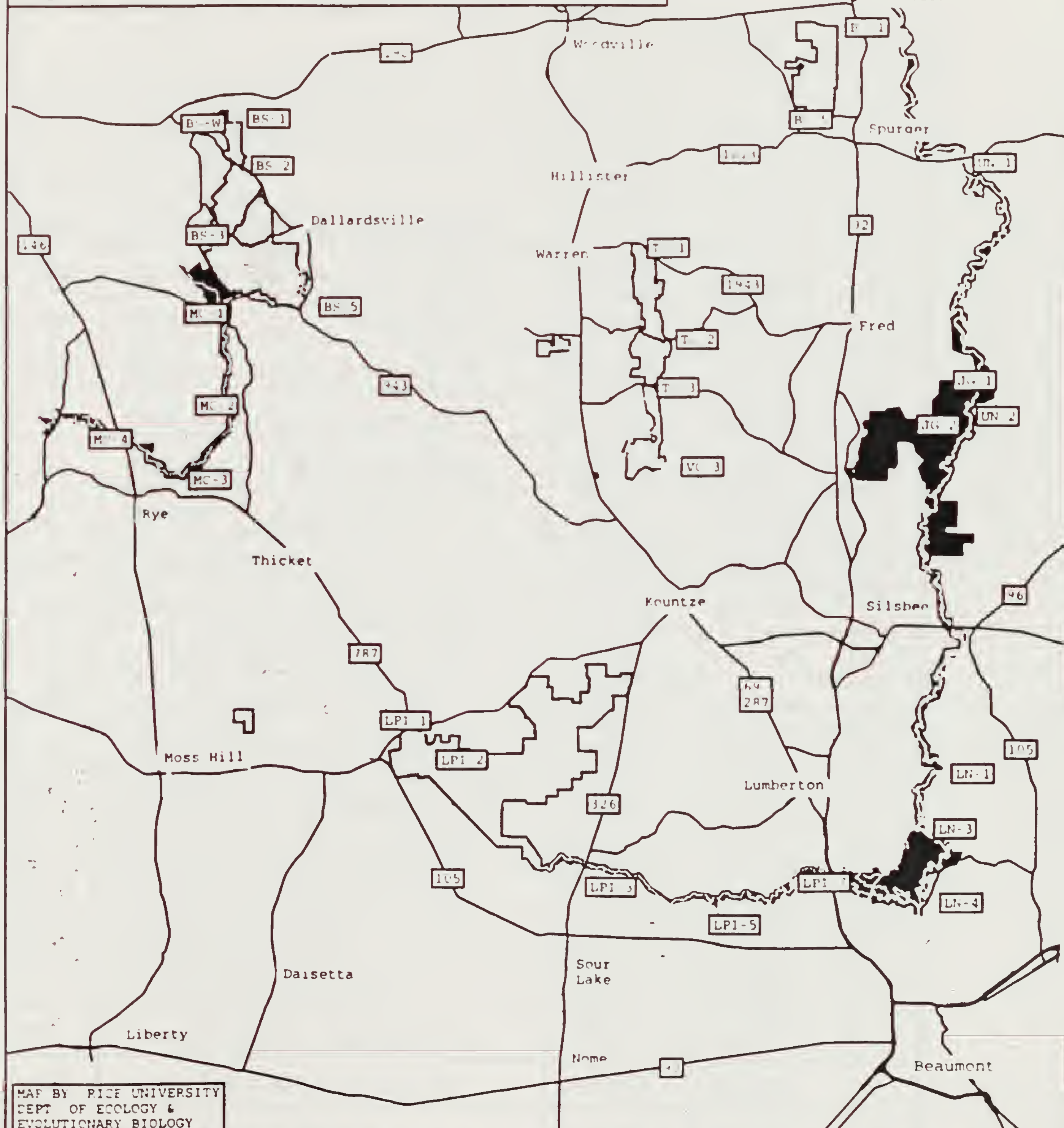
Monthly measurements have been made since 1984 of the following water quality parameters: water temperature, specific conductance, turbidity, pH, and dissolved oxygen (DO). Quarterly measurements were made of the following parameters: alkalinity, chloride, sulfate, color, TDS, TSS, oil and grease, fecal coliform, and fecal streptococcus. Field water quality measurements (*e.g.*, those made monthly) were made by NPS personnel, while the laboratory analyses of the quarterly parameters were conducted by the Water Quality Laboratory of the Trinity River Authority. A summary of the means, minima, and maxima for all monitored parameters at all BTNP stations may be found in Appendix A.

Originally, there were 24 water quality monitoring stations (Fig. 2), with one added shortly after the beginning for a total of 25 stations. Over time, budgetary and personnel constraints within NPS have reduced this number to 15 (Table 5). Monitoring was begun 11/07/84 and continues to the present. As mentioned previously, most of the monitoring stations were found on streams which are not among the water corridors which are the focus of this report. Those stations that are within the major water corridors also have less frequent sampling and most of them are not currently being monitored (all Neches River sampling ended in 1991). This is because the philosophy of the monitoring program was to focus on monitoring smaller streams more within the control of the Preserve. Despite the lack of data on the water corridors, we suggest that an analysis of the first decade of Big Thicket water quality data will assist us in identifying potential trends and problems within the corridors, since most monitored streams are tributaries of the major streams defined as corridors.

Description of USGS Sampling Program

The USGS has six stations within the study area at which numerous water quality parameters have been monitored quarterly (Fig. 3 ; Table 6). A summary of the means, minima, and maxima for all monitored parameters at all six stations may be found in Appendix B. Certain parameters have been measured only for the station on the Neches River at Evadale (see Appendix B). Current monitoring is occurring only at the Evadale station.

BIG THICKET NATIONAL PRESERVE
Water Corridor Management Plan
Fig. 2. Water Quality Sampling Locations



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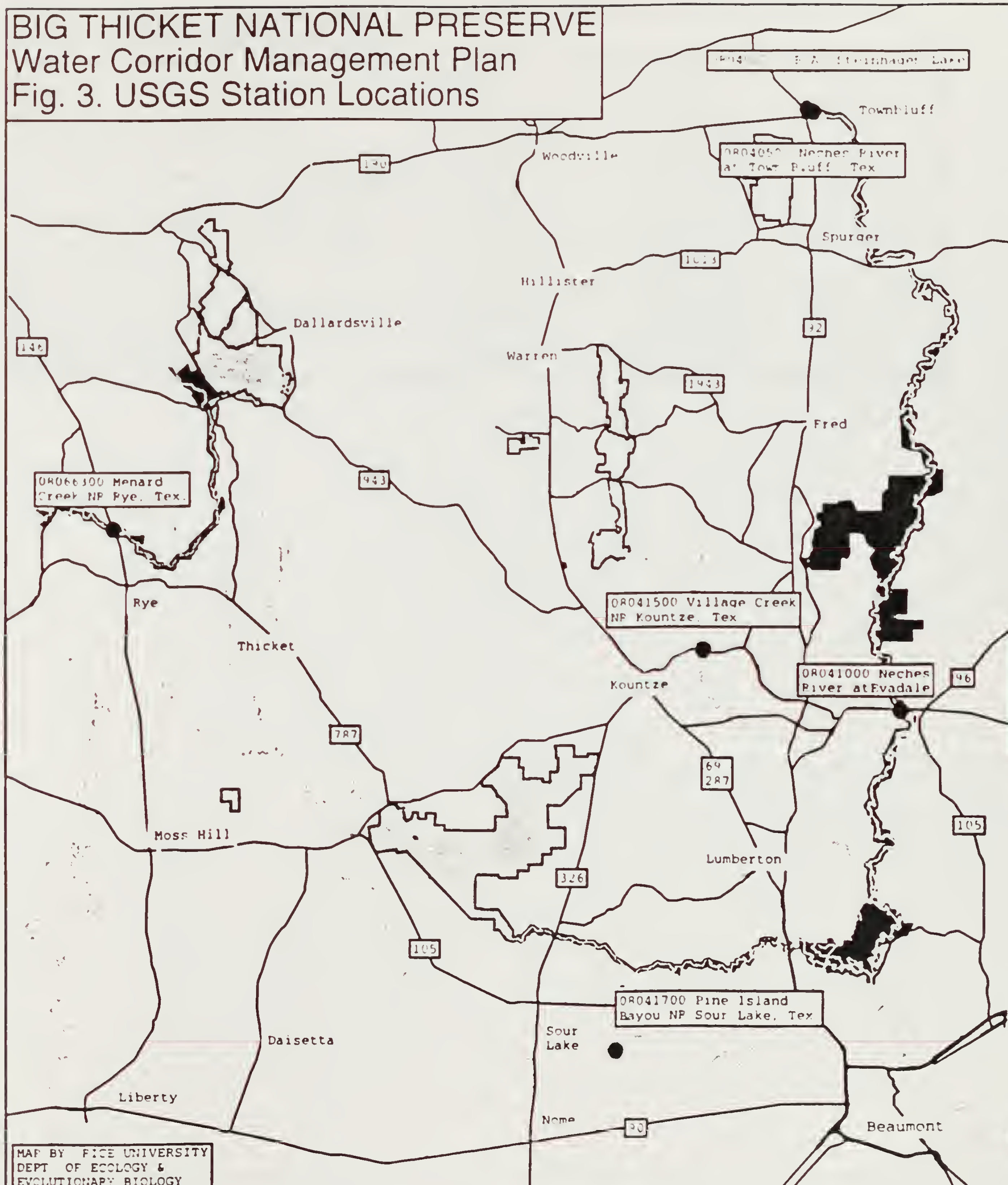
REGION: 320005 3415993.6 404405 3319033.6

Table 5. Beginning and ending dates of water quality sampling, and total number at each location for BTNP water quality program.

	SITE	FIRST	LAST	N
BC1	Beech Creek at Best Rd.	11/07/84	04/20/92	76
BC5	Beech Creek at South Boundary	11/07/84	08/12/94	92
BS1	Mill Creek	11/07/84	07/13/92	94
BS2	Big Sandy Creek at FM1276 North	11/07/84	08/12/94	93
BS3	Big Sandy Creek at Sunflower Rd.	11/07/84	08/12/94	93
BS5	Big Sandy Creek at FM1276 South	11/07/84	08/12/94	95
BSW	Big Sandy Creek at Woodlands Tr.	07/30/85	04/17/92	26
JG2	Black Creek above Sandlot Lake	01/08/84	12/04/89	56
JG2	Black Creek at Timber Slough Rd.	01/08/84	12/04/89	38
LN1	Neches River at Weiss Bluff	01/10/85	09/11/91	23
LN3	Neches River at Lakeview	01/10/85	08/11/94	25
LN4	Neches River at Pine Island Bayou	01/10/85	09/11/91	22
LPI1	Little Pine Island Bayou at FM770	01/07/84	08/11/94	95
LPI2	Little Pine Island B. at Teel Rd.	01/07/84	08/11/94	92
LPI3	Little Pine Island Bayou at SH326	01/07/84	08/11/94	94
LPI5	Little Pine Is. B. at Bevil Oaks	01/07/84	08/11/94	94
LPI7	Little Pine Island B. at US 69/96	01/07/84	08/11/94	93
MC1	Menard Creek at FM943	01/07/84	08/11/94	93
MC4	Menard Creek at SH146	01/07/84	08/11/94	93
TC1	Turkey Creek at FM 1943	01/08/84	08/12/94	93
TC2	Turkey Creek at Hicksbaugh Rd.	01/08/84	08/12/94	94
TC3	Turkey Creek at County Line Rd.	01/08/84	08/12/94	95
UN1	Neches River at FM1013	01/10/85	09/11/91	22
UN2	Neches River at Timber Slough Rd.	01/08/84	10/03/89	7
VC3	Village Creek at McNeely Bridge	01/08/84	08/11/94	93



BIG THICKET NATIONAL PRESERVE
Water Corridor Management Plan
Fig. 3. USGS Station Locations

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REGION: 320005 404405 3415993.6 3319033.6

Table 6. Beginning and ending dates of water quality sampling, and total number at each location for USGS water quality program.

Station	First	Last	N
08040500-Steinhagen Lake	01/13/81	08/15/89	51
08040600-Neches River @ Town Bluff	11/15/89	08/29/91	12
08041000-Neches River @ Evadale	10/01/67	03/08/93	352
08041500-Village Creek	11/01/67	09/06/85	184
08041700-Pine Island Bayou	02/01/68	06/30/89	289
08066300-Menard Creek	10/30/67	08/13/92	203

Description of Seasonal Patterns

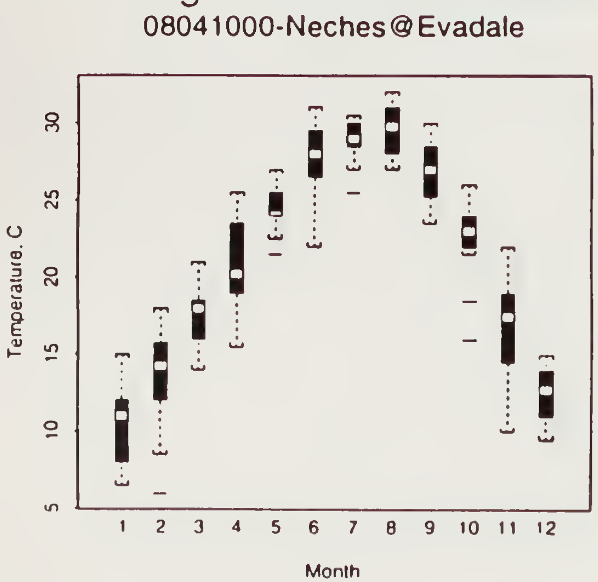
Seasonal patterns for selected parameters are represented by boxplots by month for eight selected stations (Fig. 4-11) from both Big Thicket and USGS datasets. Four of the eight are USGS stations (Fig. 4 -Neches River at Evadale, Fig. 6 - Pine Island Bayou, Fig. 8 - Menard Creek, Fig. 10 - Village Creek). Four are BTNP stations (Fig. 5 - BS1, Fig. 7 - LPI1, Fig. 9 - MC1, and Fig. 11 - VC3). Three streams are represented by both a USGS station and a BTNP station, allowing for comparisons between the two datasets (Pine Island Bayou, Little Pine Island Bayou, and Menard Creek). The USGS Neches River station was selected because of its long record, while BTNP station BS1 was selected to represent smaller Big Thicket streams like Big Sandy, Beech, Turkey and Black Creeks. Six parameters are shown for each station, and across the figures, parameters are the same except that for USGS stations, discharge is shown (in the middle figure of the top row), while for BTNP stations, DO is shown (in the same position).

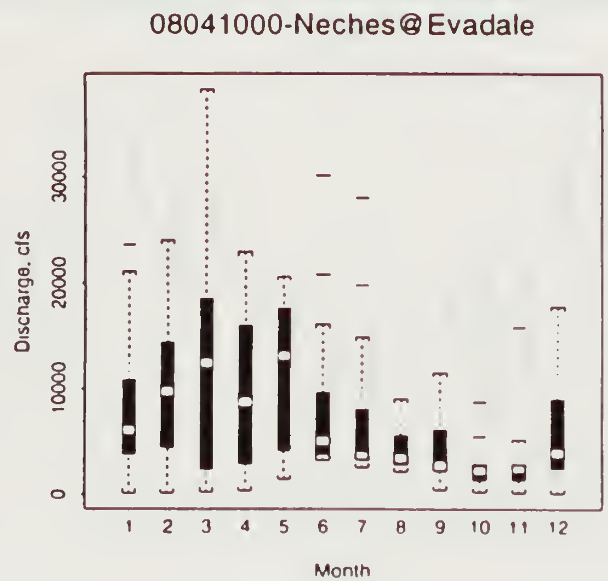
Boxplots (also called box-and-whisker plots) are indicators of the location (central tendency) of datasets which are resistant to the effects of outliers. The arithmetic mean and standard deviation are more common indicators of location, but these statistics can be greatly affected by outliers. The box encloses the interquartile range of the values in the dataset, with a horizontal line indicating the median. The extended vertical lines (whiskers) outside the boxes represent a range of 1.5 times the interquartile range. By convention, the whiskers are drawn to the farthest value not outside an envelope of 1.5 times the interquartile range, centered on the median. Any individual points outside this range or cutoff may be classified as true outliers. Outliers outside the cutoffs are plotted individually. Since each dataset represented a number of years of data, each boxplot represents between-year variability for each parameter for each month.

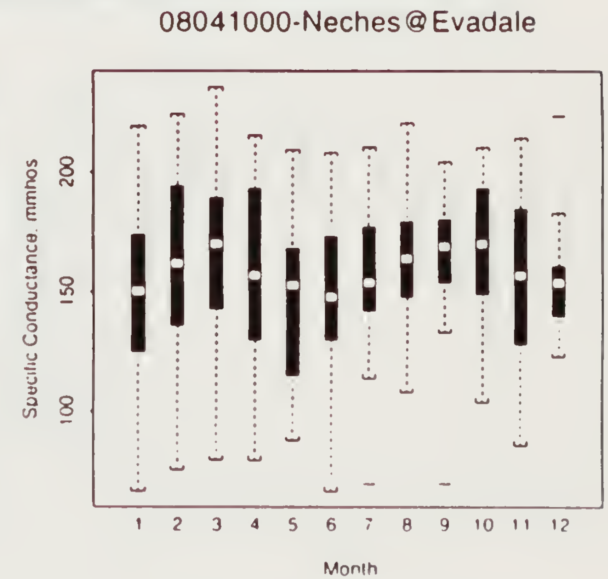
Seasonal temperature variations among all streams were consistent, with little variation among streams. Between-year variability of water temperature appeared to be greater in the fall than in the spring, and lowest in mid-summer. This pattern was consistent among sites. Median temperatures were lowest in January (below 10°) and highest in July (about 28°).

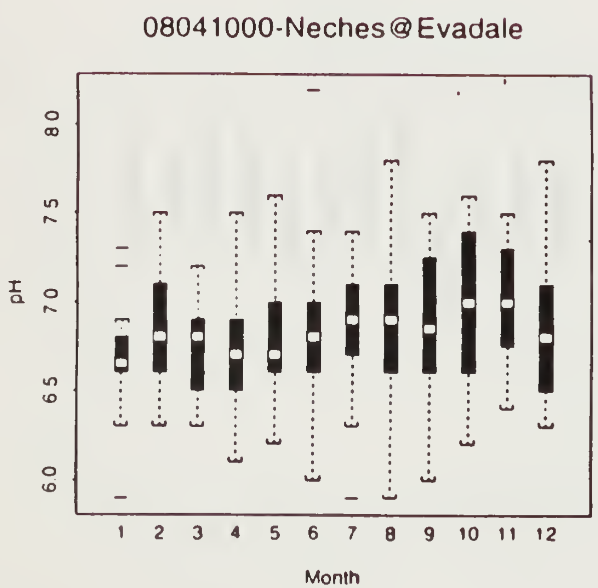
Discharge tended to be both greater and more variable in the spring, while it was lower and less variable in the summer months (USGS Stations, Fig. 4, 6, 8, and 10). Dissolved oxygen

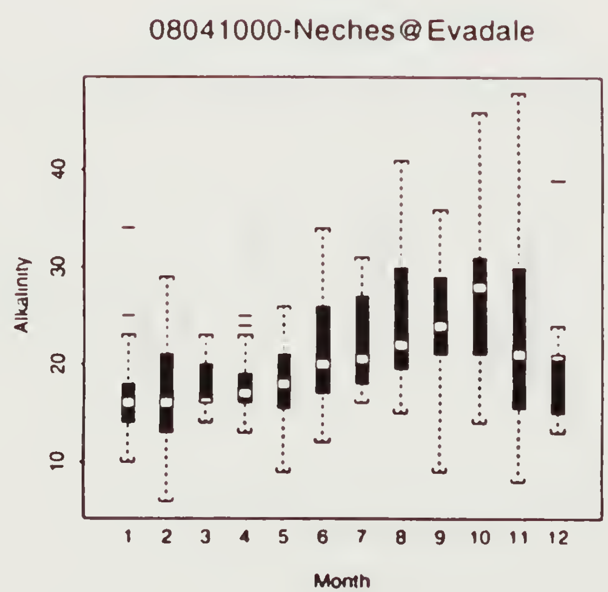
Fig. 4 Seasonal Patterns for Selected Parameters at 08041000-Neches@Evadale











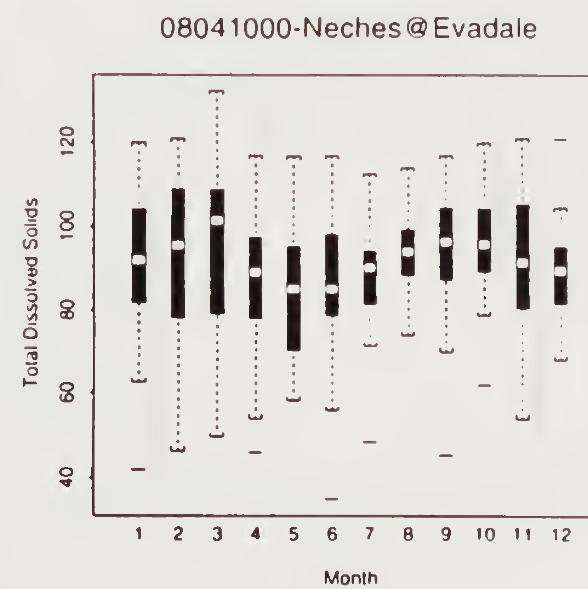


Fig. 5 Seasonal Patterns for Selected Parameters at BS1

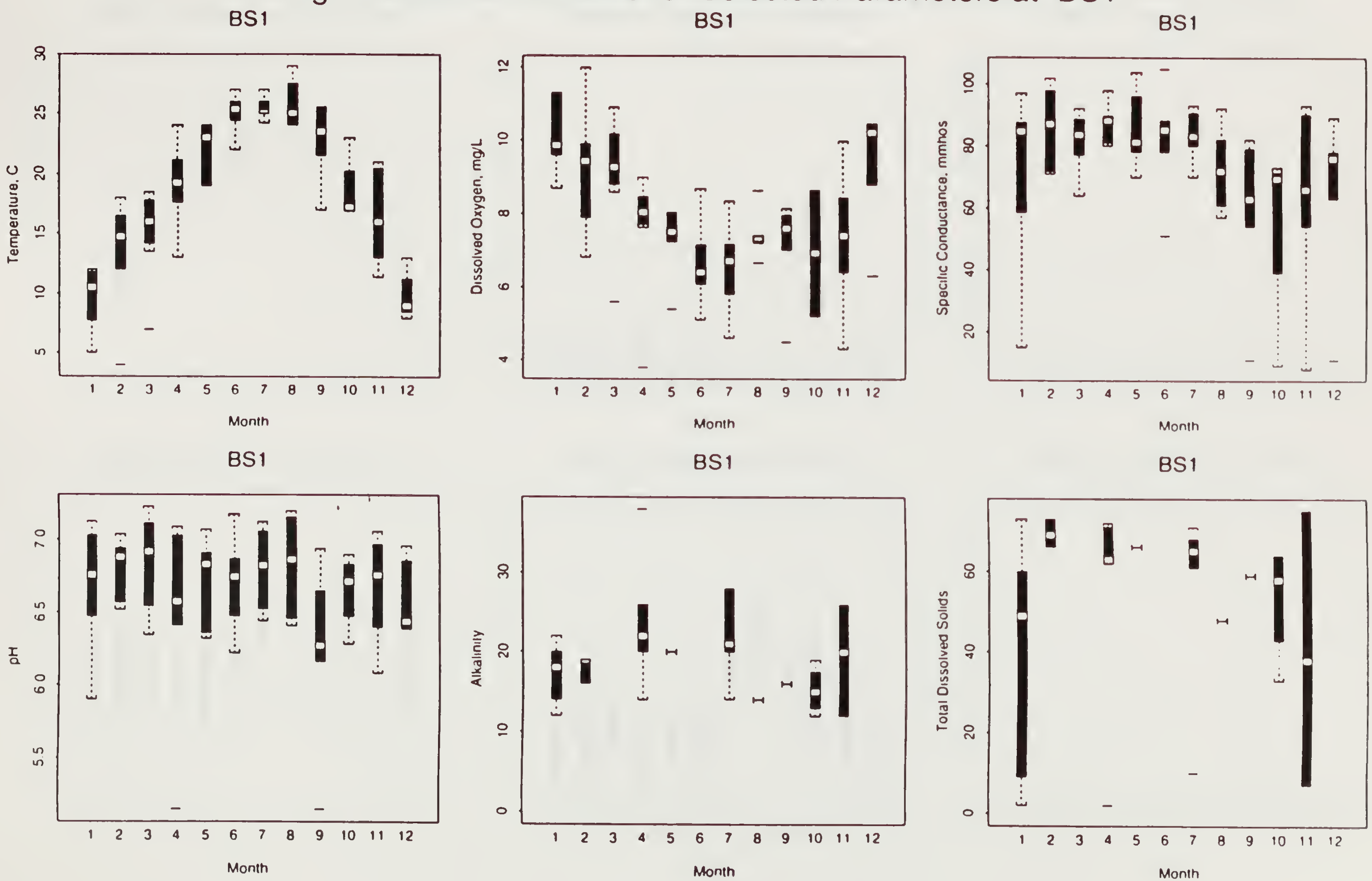


Fig. 6 Seasonal Patterns for Selected Parameters at 08041700-Pine_Island_Bayou

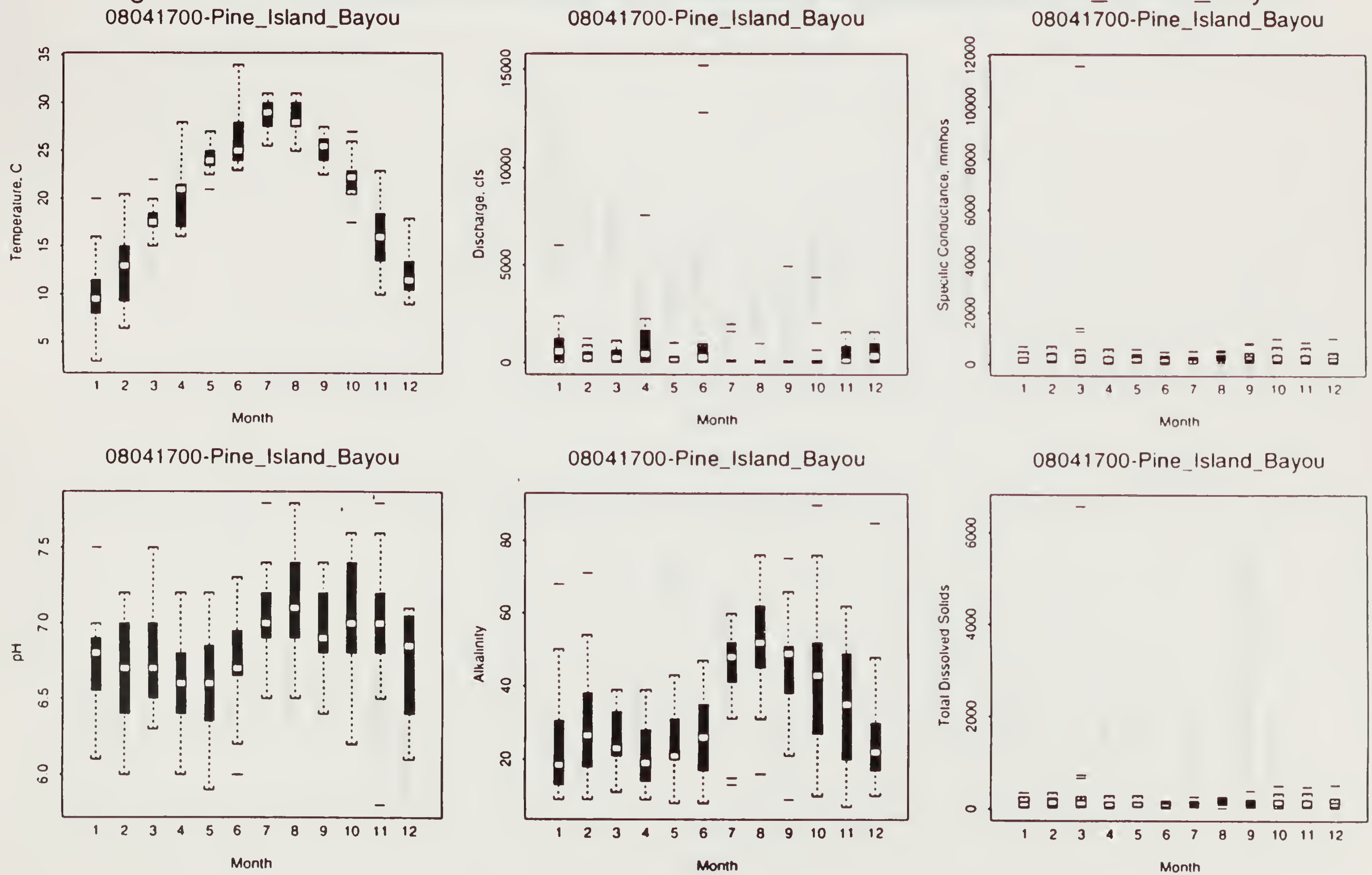


Fig. 7 Seasonal Patterns for Selected Parameters at LPI1

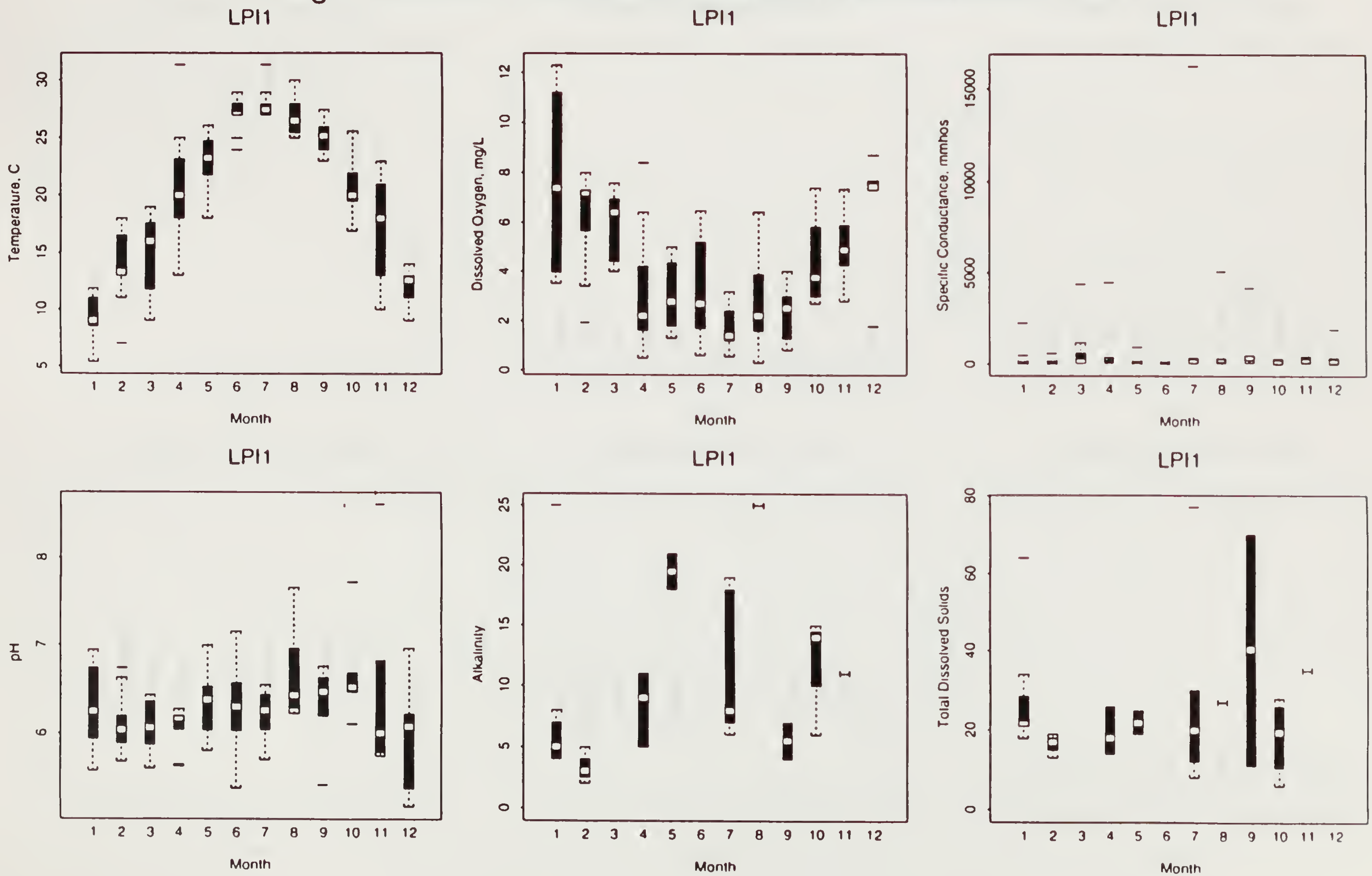


Fig. 8 Seasonal Patterns for Selected Parameters at 08066300-Menard_Creek

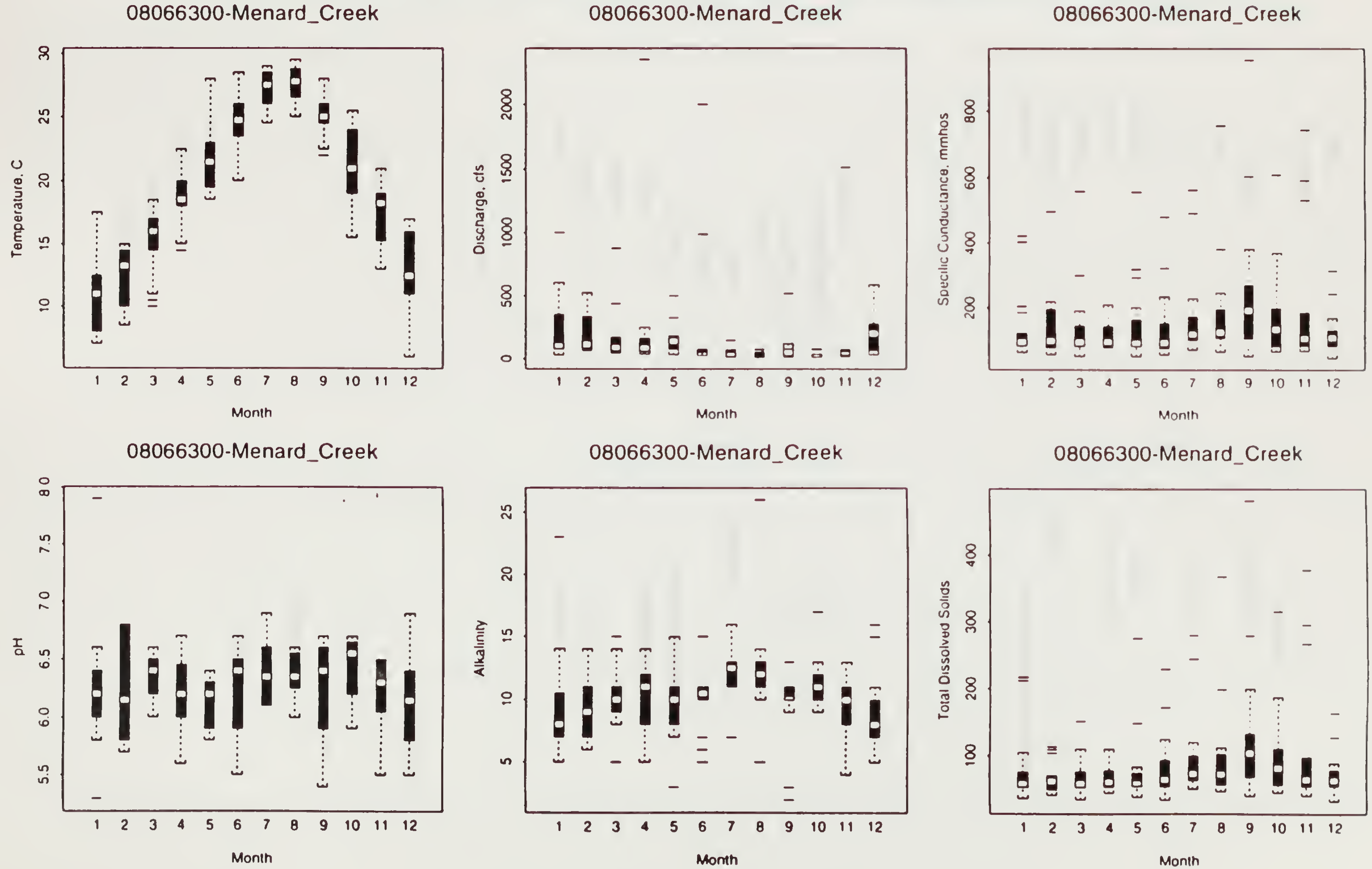


Fig. 9 Seasonal Patterns for Selected Parameters at MC1

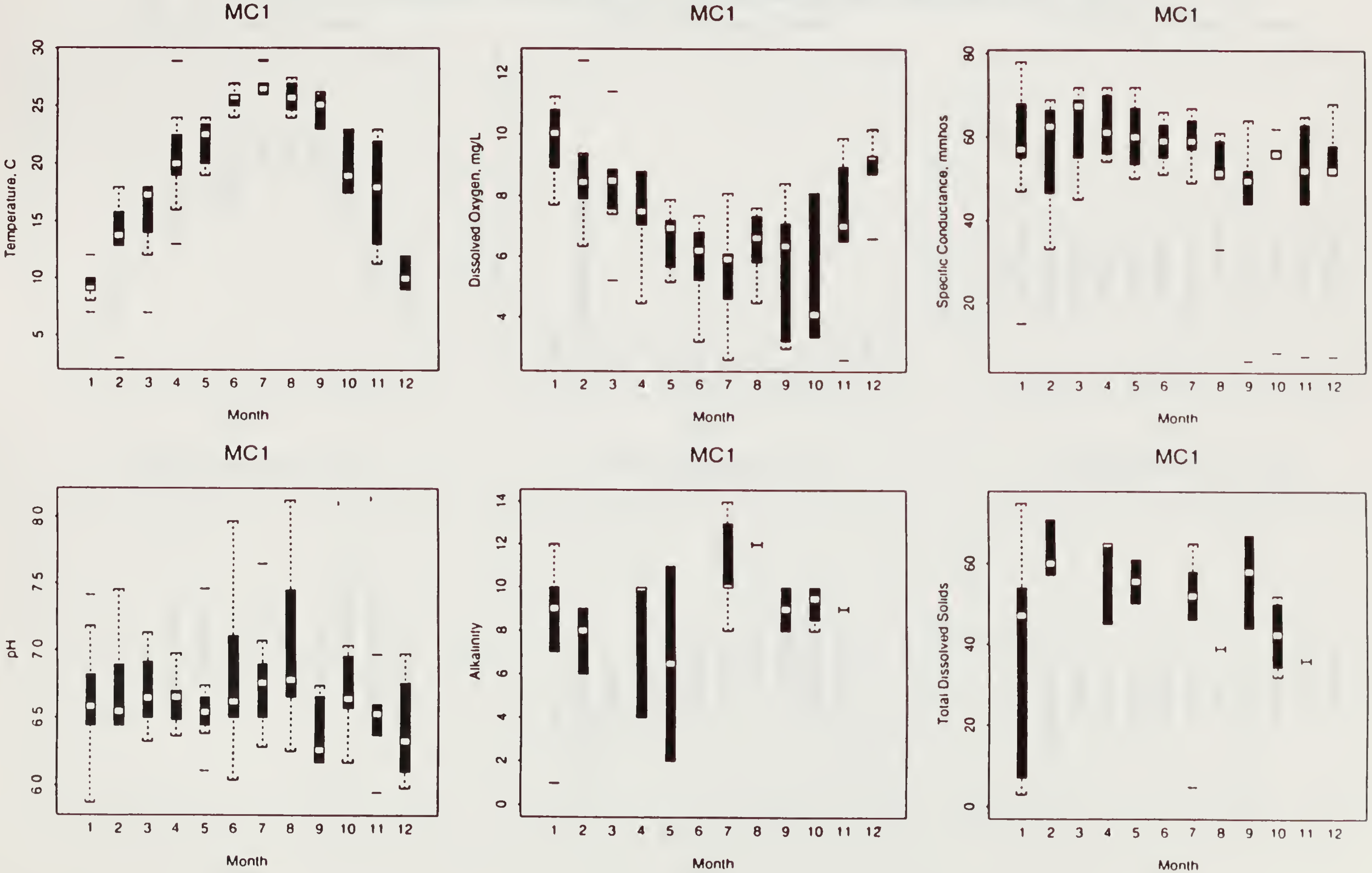
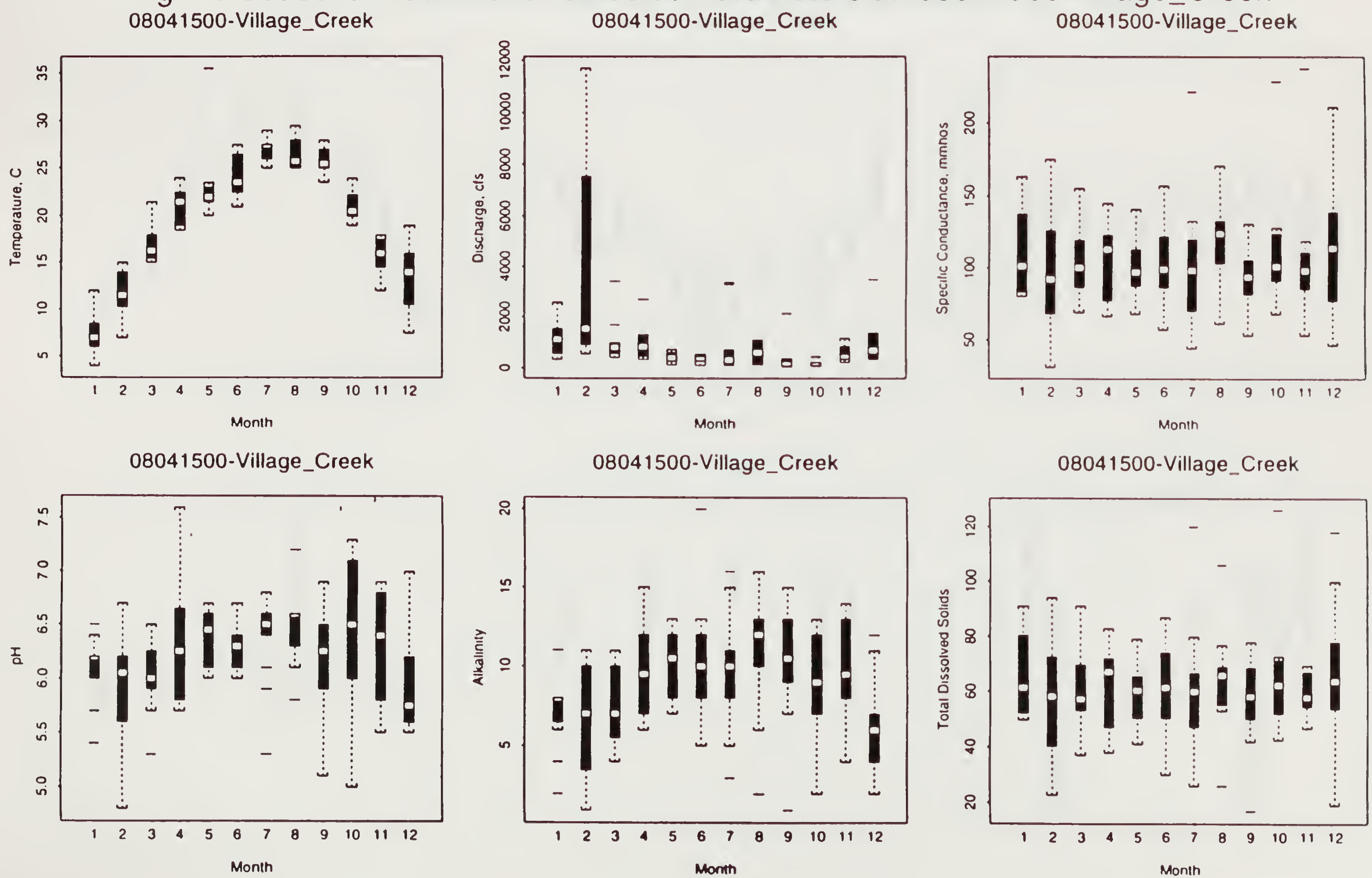


Fig. 10 Seasonal Patterns for Selected Parameters at 08041500-Village_Creek



was highest in winter and lowest in summer (BTNP stations, Fig. 5, 7, 9, and 11). The majority of this variation was related to water temperature. For Menard Creek (Fig. 9) and Big Sandy (Fig. 5), low dissolved oxygen in October despite cooler temperature may indicate an influx of organic matter associated with leaf-fall. Little Pine Island Bayou (Fig. 7) had a slightly different pattern, with low dissolved oxygen from April to October.

In all streams, there was no clear seasonal pattern of variation in pH or specific conductance (Fig. 4-11), but alkalinity seemed to peak in late summer for several locations (Fig. 6, 8, and 10). In general, low numbers of observations at BTNP stations (alkalinity was measured only quarterly) make it difficult to interpret the seasonal pattern of alkalinity data from these stations, but the USGS stations contained more complete monthly data. Alkalinity is a measure of the ability of a water sample to neutralize acids. This represents its buffering capacity, or its ability to resist a drop in pH. In natural waters, high alkalinity may indicate high algae populations which have reduced CO_2 concentrations to very low levels (Sawyer and McCarty, 1967). Such waters can have high pH, from 9-10. Thus, the summer peak in alkalinity might indicate favorable conditions for algae.

Seasonal patterns for TDS were not strong, but were probably related to discharge. Since specific conductance values are related to TDS, these two parameters should be correlated (Sawyer and McCarty, 1967). They appeared to be correlated for the USGS stations, for which more frequent data collection made the seasonal patterns clearer.

Overall Comparisons Among Stations

Stations along the same watercourse were generally similar in location and spread of their distributions of pH measurements (Fig. 12). Beech Creek (BC1 and 5) and Black Creek (JG1 and JG2) had the lowest pH, while the Neches River stations (LN1, 3, and 4 and UN1 and 2) had the highest. Within a stream, the five Little Pine Island Bayou stations (LPI1, 2, 3, 5, and 7) showed the greatest variation, with pH increasing toward the downstream end. Stations along the same watercourse were also generally similar in dissolved oxygen (Fig. 13), again with Little Pine Island Bayou (LPI1-7) showing the most variation, and a systematic increase toward the

Fig. 12. pH for BTNP Sample Locations

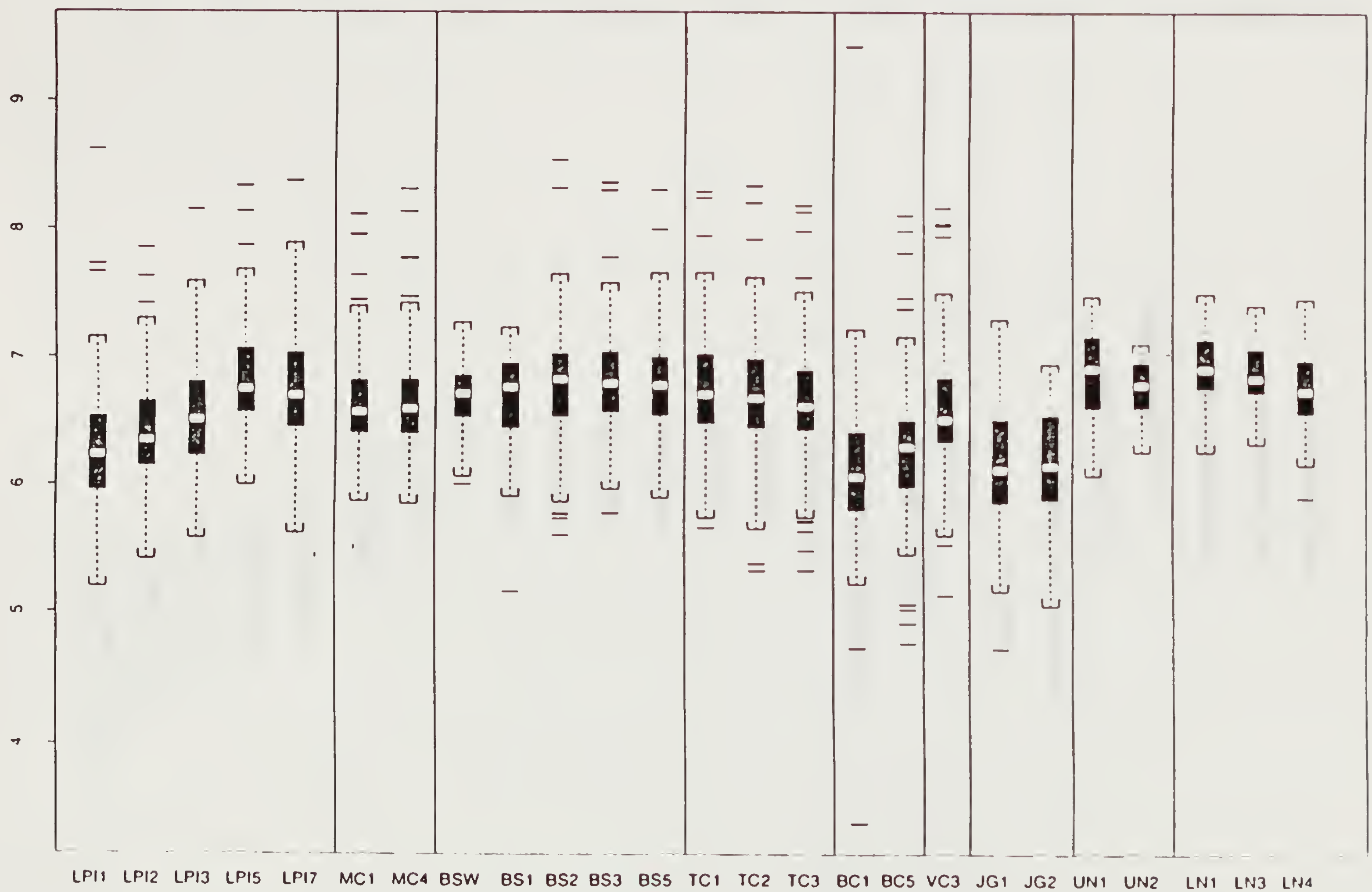
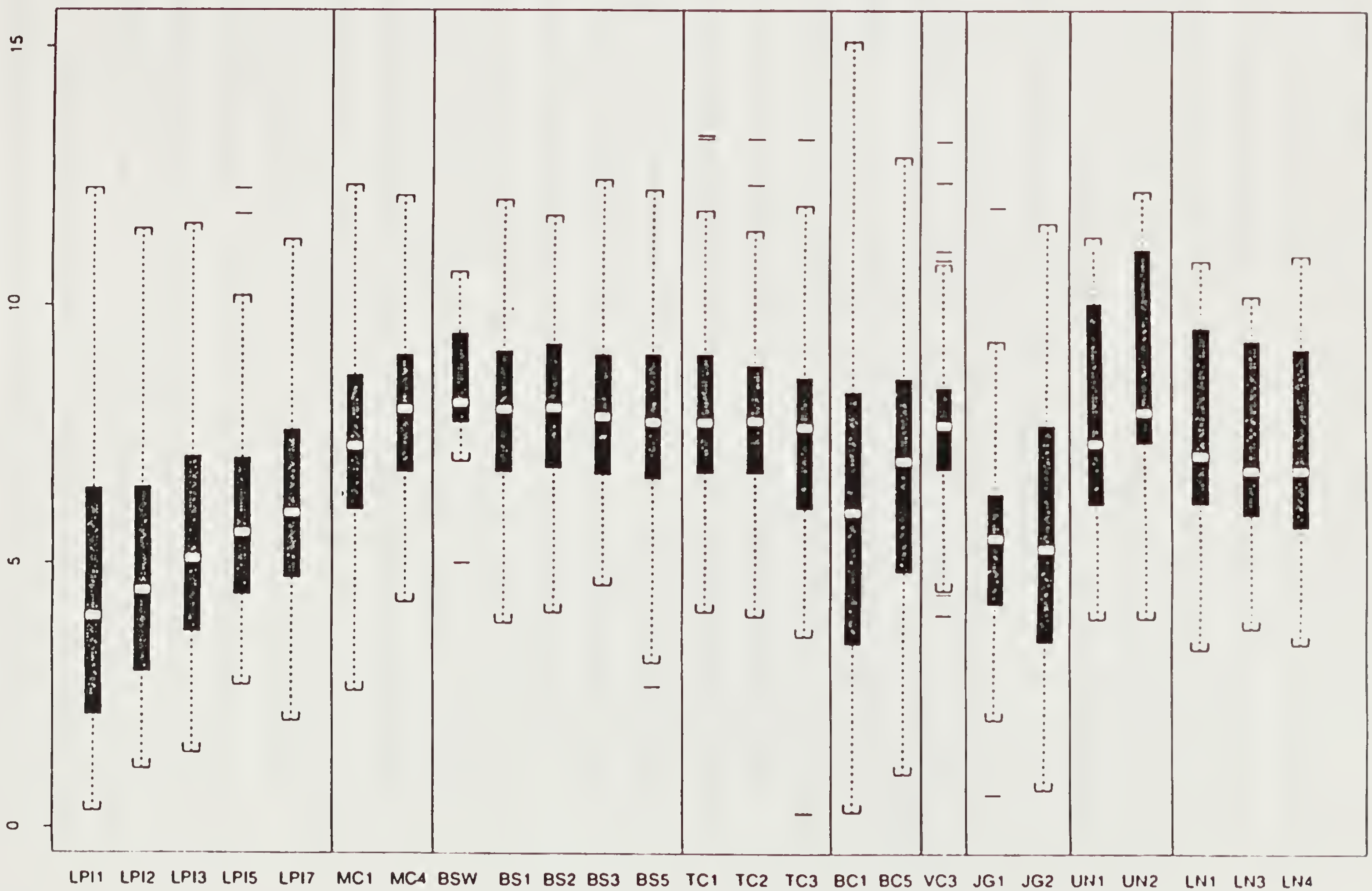


Fig. 13. Dissolved Oxygen for BTNP Sample Locations



downstream end. Beech Creek, Black Creek, and Little Pine Island Bayou had the lowest overall dissolved oxygen.

At LPI5 and LPI7, turbidity values were very much higher than for all other stations (Fig. 14). The contrast of these two stations with those upstream on Little Pine Island Bayou suggests that the segments are of very different character: clearly certain elements of the water chemistry of Little Pine Island Bayou change as it progresses downstream. Because these two stations are downstream of the confluence of Pine Island Bayou with Little Pine Island Bayou, this could have resulted from a difference in parent material. These findings were again consistent with the findings of Hughes *et al.* (1987), but different from the findings of Darville (1978) who found lower turbidities toward the downstream end of Little Pine Island Bayou.

Comparative TSS (Fig. 15) values confirmed the difference between upper Little Pine Island Bayou and Pine Island Bayou below the confluence: LPI5 and LPI7 showed much higher TSS readings than did LPI1-3. Stations with highest TSS were lower Neches stations (LN1, 2, and 3). Regional patterns were similar for TDS (Fig. 16). Comparing all sites, the Little Pine Island Bayou sites were substantially higher in TDS than the other sample locations, while Menard Creek and Turkey Creek were lower. The downstream Menard Creek station (MC4) showed greater TDS than the upstream station (MC1). This is consistent with the findings of Hughes *et al.* (1987). Specific conductance, which is often used as a quick estimate of TDS (Sawyer and McCarty, 1967), showed patterns consistent with the TDS data (Fig. 17).

There was much variation in alkalinity in the region (Fig. 18). There were several streams with very low (~10) alkalinity (Beech Creek, Black Creek, the upper Little Pine Island Bayou stations, Menard Creek, Turkey Creek, and Village Creek). Again, Little Pine Island Bayou changed radically in character moving downstream, with a clear break between the upper stations (LPI1, 2, and 3) and the lower stations (LPI5 and 7). Overall, the lower stations had higher alkalinity than any other sampled steams. This pattern is consistent with that found by Hughes *et al.* (1987), who suggested that Little Pine Island Bayou had a characteristically higher alkalinity compared to other Big Thicket streams because the channel flows through parent material from the Beaumont formation, which is more calcareous. Given that the lower reaches of Little Pine Island Bayou drain lands to the south, primarily in the Beaumont formation, the differences in

Fig. 14. Turbidity for BTNP Sample Locations

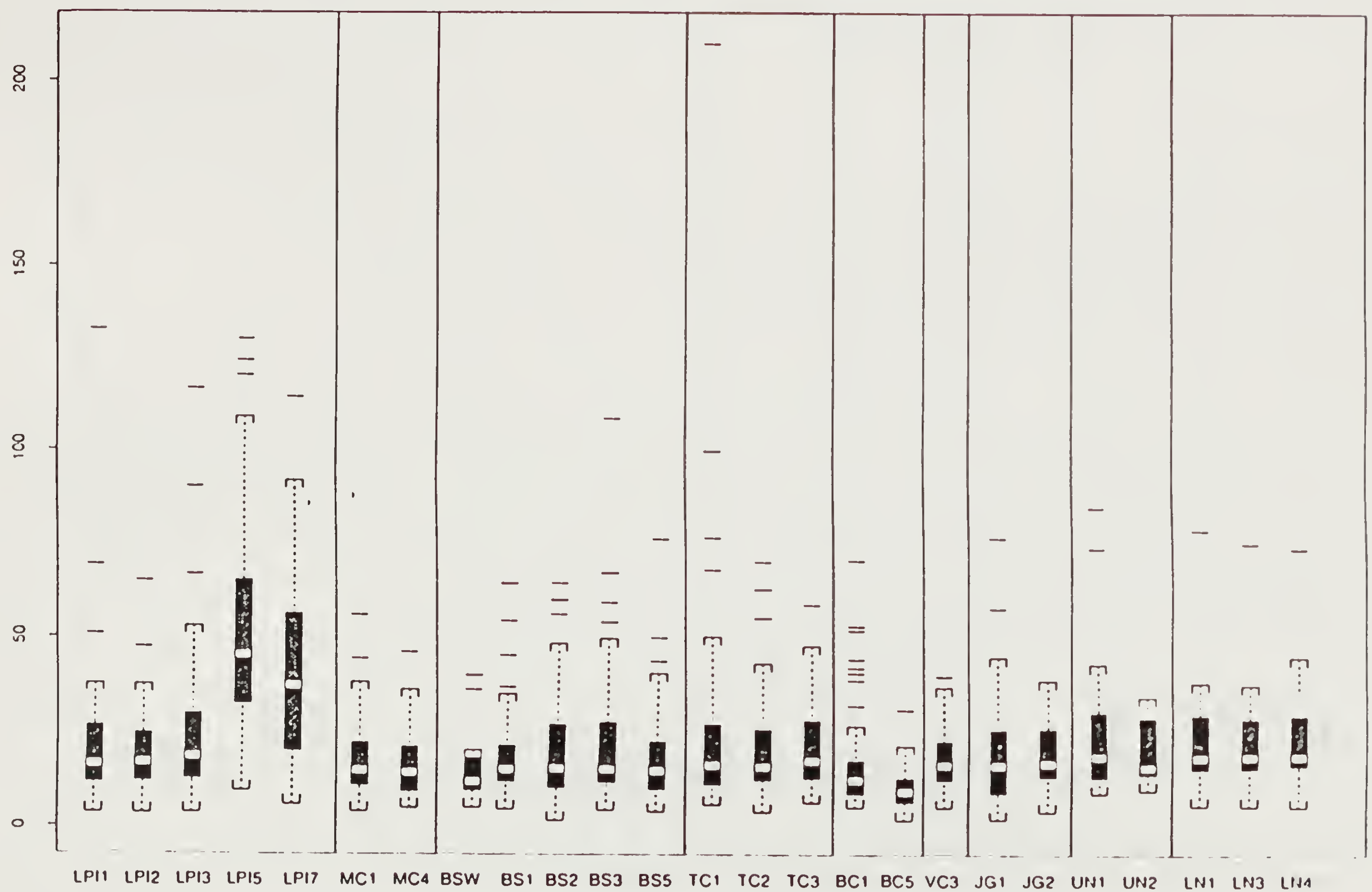


Fig. 15. TSS for BTNP Sample Locations

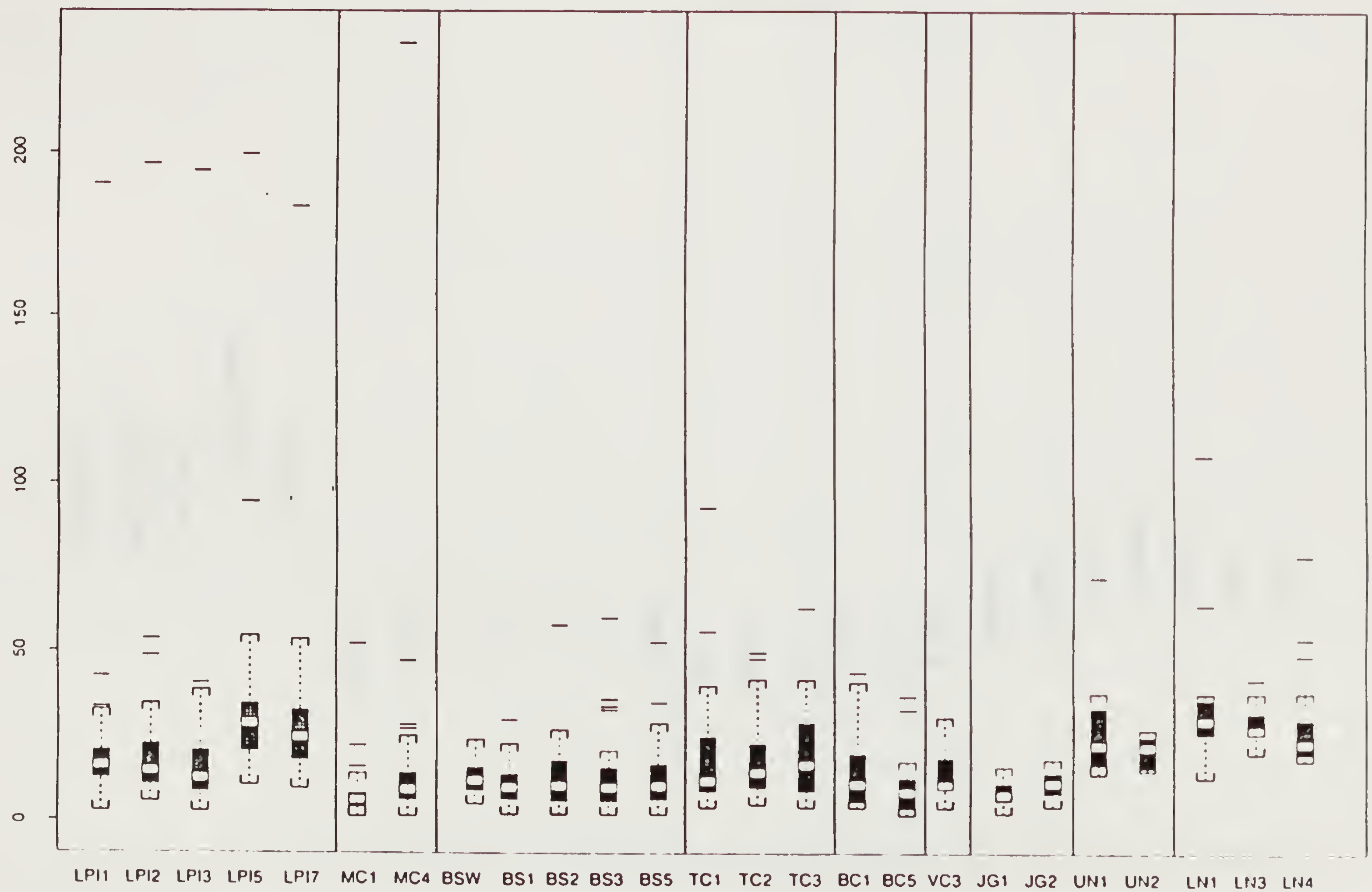


Fig. 16. TDS for BTNP Sample Locations

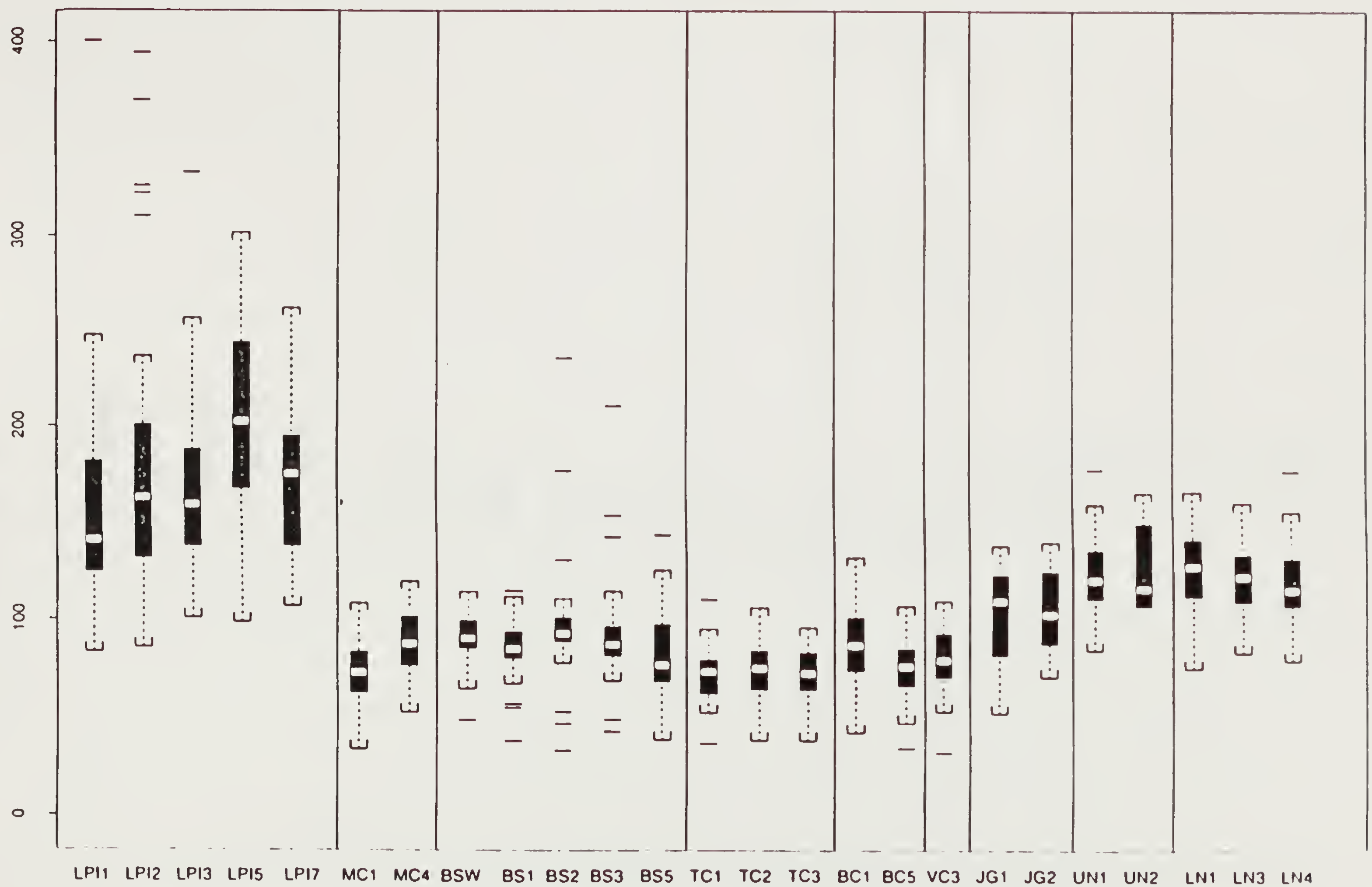


Fig. 17. Log of Specific Conductance for BTNP Sample Locations

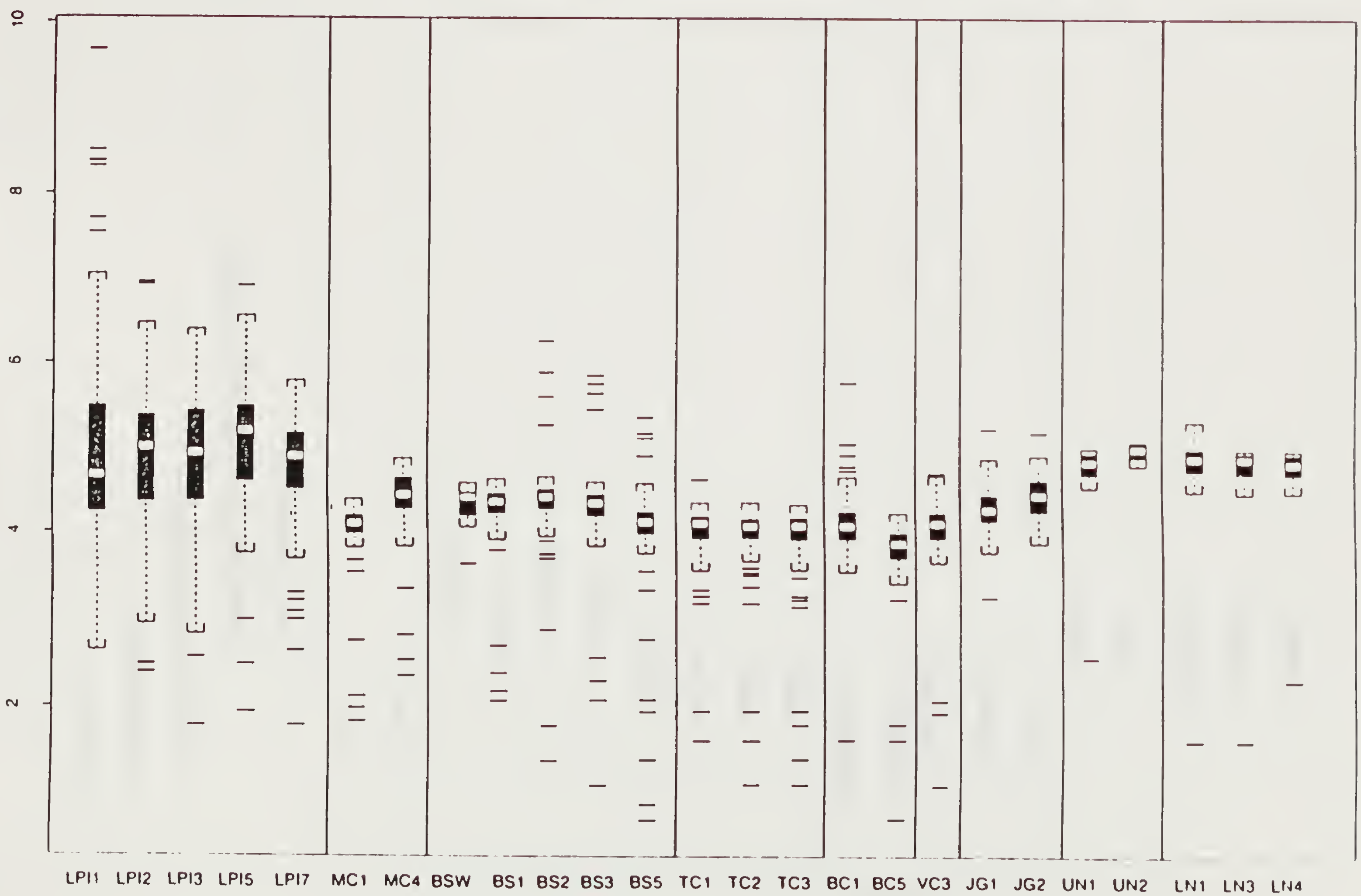
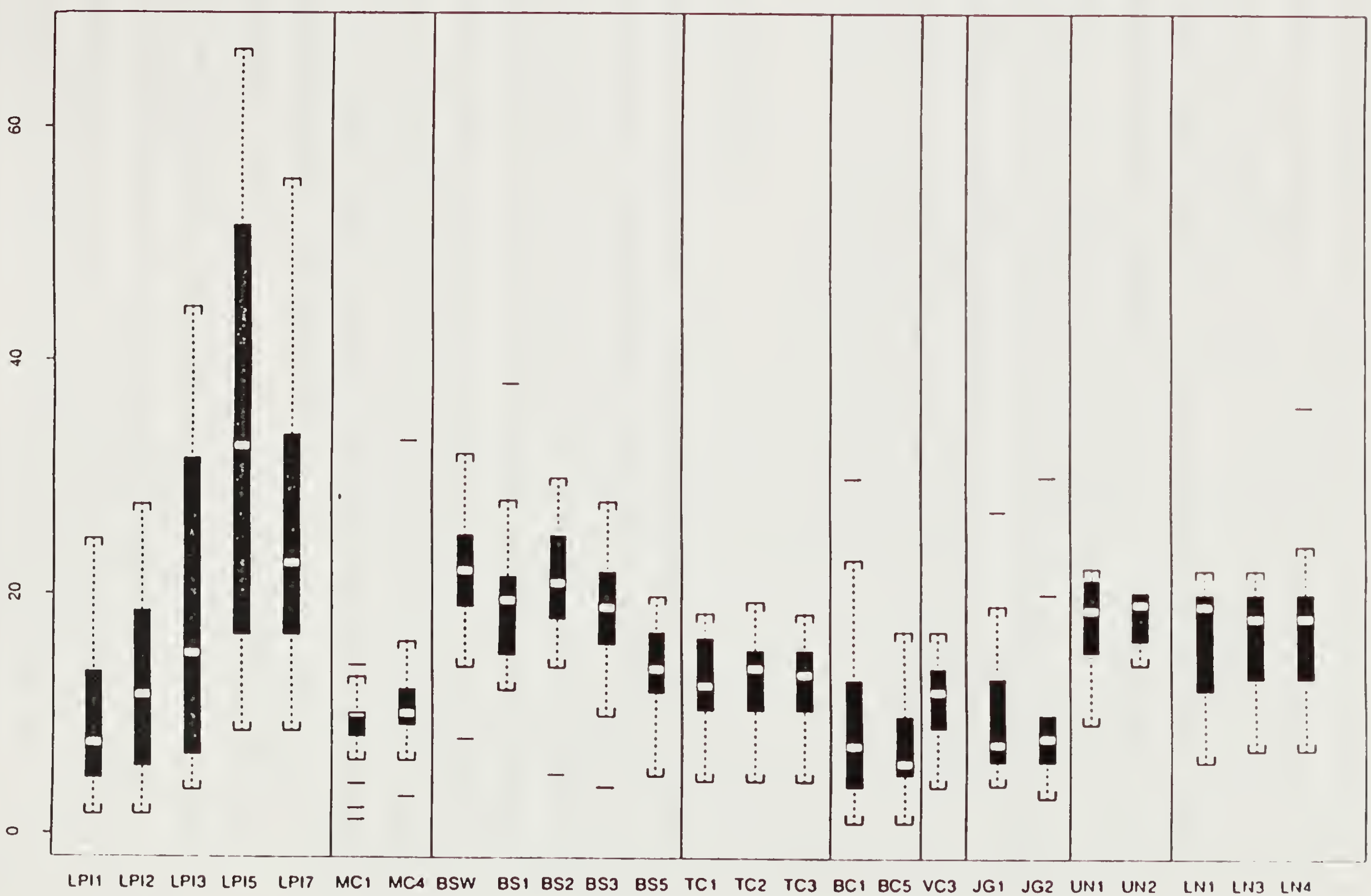


Fig. 18. Alkalinity for BTNP Sample Locations



alkalinity very likely result from this difference in parent material. They also suggested that the downstream elevation in alkalinity at LPI4, 5,and 6 may have been related to discharge from the Pinewood Estates sewage treatment plant.

Elevated chloride concentrations (Fig. 19) found at LPI1, 2, 3, 5, and 7 and MC4 have been attributed by previous authors (Hughes *et al.* 1987 and Darville 1978) to contamination by waste brines from the Sour Lake and Saratoga oil fields on Little Pine Island Bayou and from Schwab oil field on Menard Creek. Sulfate (Fig. 20) shows a similar pattern, with higher sulfates at all Neches River stations in addition to Little Pine Island Bayou. According to Hughes *et al.* (1987), elevated sulfates may also be related to discharge of oil field wastes.

Elevated bacterial concentrations are found throughout the region (Fig. 21), with stations on Big Sandy (BS1 and 2) and on Little Pine Island Bayou (LPI3) having the highest median levels of fecal coliform bacteria per 100 mL of water. Median concentrations for fecal streptococcus were generally higher than for fecal coliform (Fig. 22).

Description of Long-Term Patterns

The long-term records for each parameter were tested for the presence of linear trends using the Pearson product-moment correlation coefficient (Table 7). This statistic ranges from -1 to 1, with values near zero indicating no trend, negative values indicating a decline with time and positive values indicating an increase with time. Before calculation of the correlation coefficient, the data were corrected for intrinsic seasonal patterns by subtracting the long-term monthly mean from each value (e.g., the mean of all January observations was subtracted from each observation made during January). The residuals from the seasonal correction were then tested for correlation with the date of the sample expressed as a SAS date value, which is an integer expressing the number of days between January 1, 1960 and that date. Approximate 1% significance levels for the correlation coefficient were calculated by permutation as follows. Sample values and sample dates were randomly permuted 99 times and correlation coefficients were calculated for each permutation. Permutations were done separately for each measurement variable at each location. If the actual correlation coefficient was outside the range of those obtained by random permutation of the data, then the individual trend was deemed significant at the 0.01 level.

Fig. 19. Chloride Concentration for BTNP Sample Locations

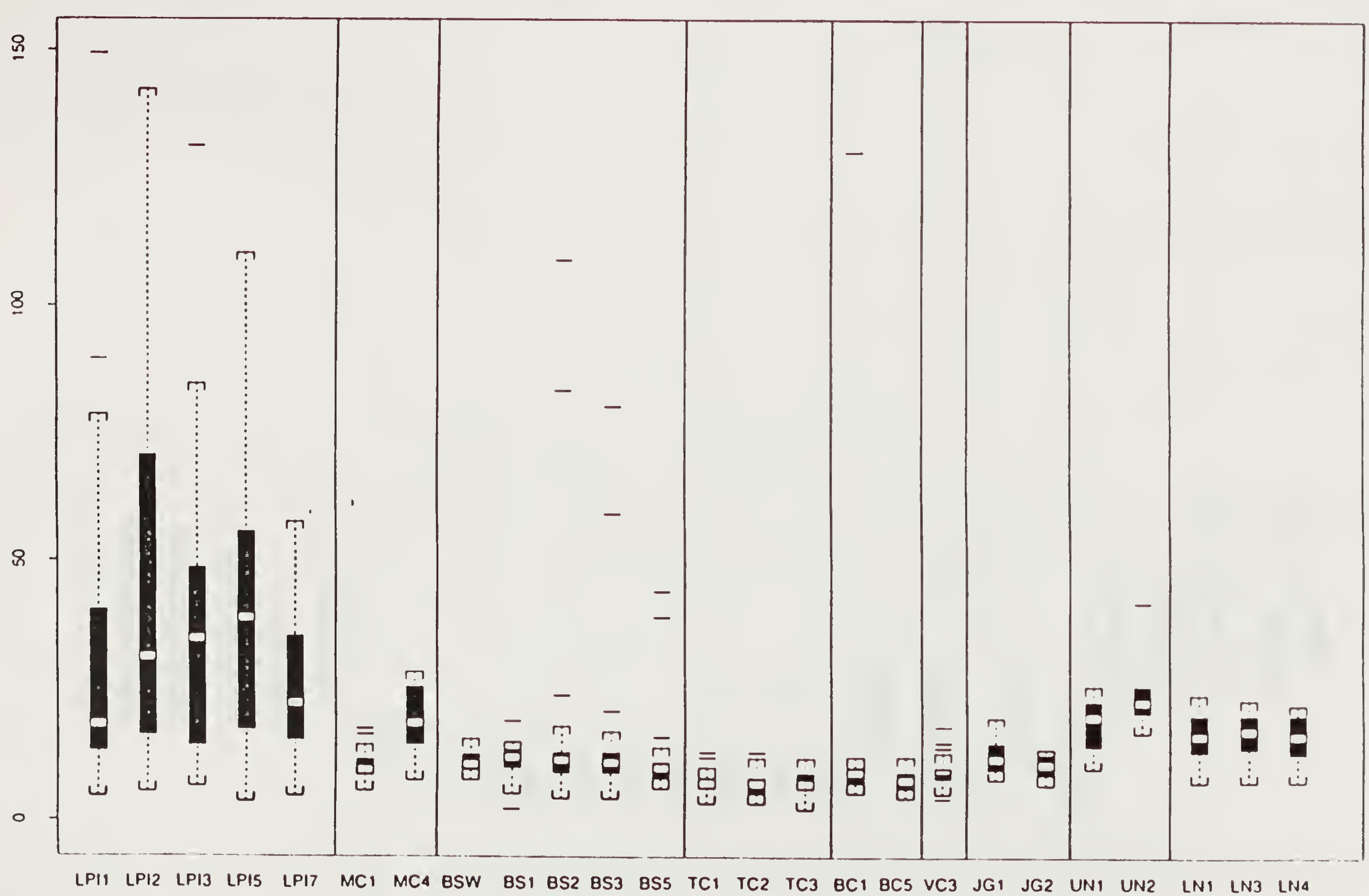


Fig. 20. Sulfate Concentrations for BTNP Sample Locations

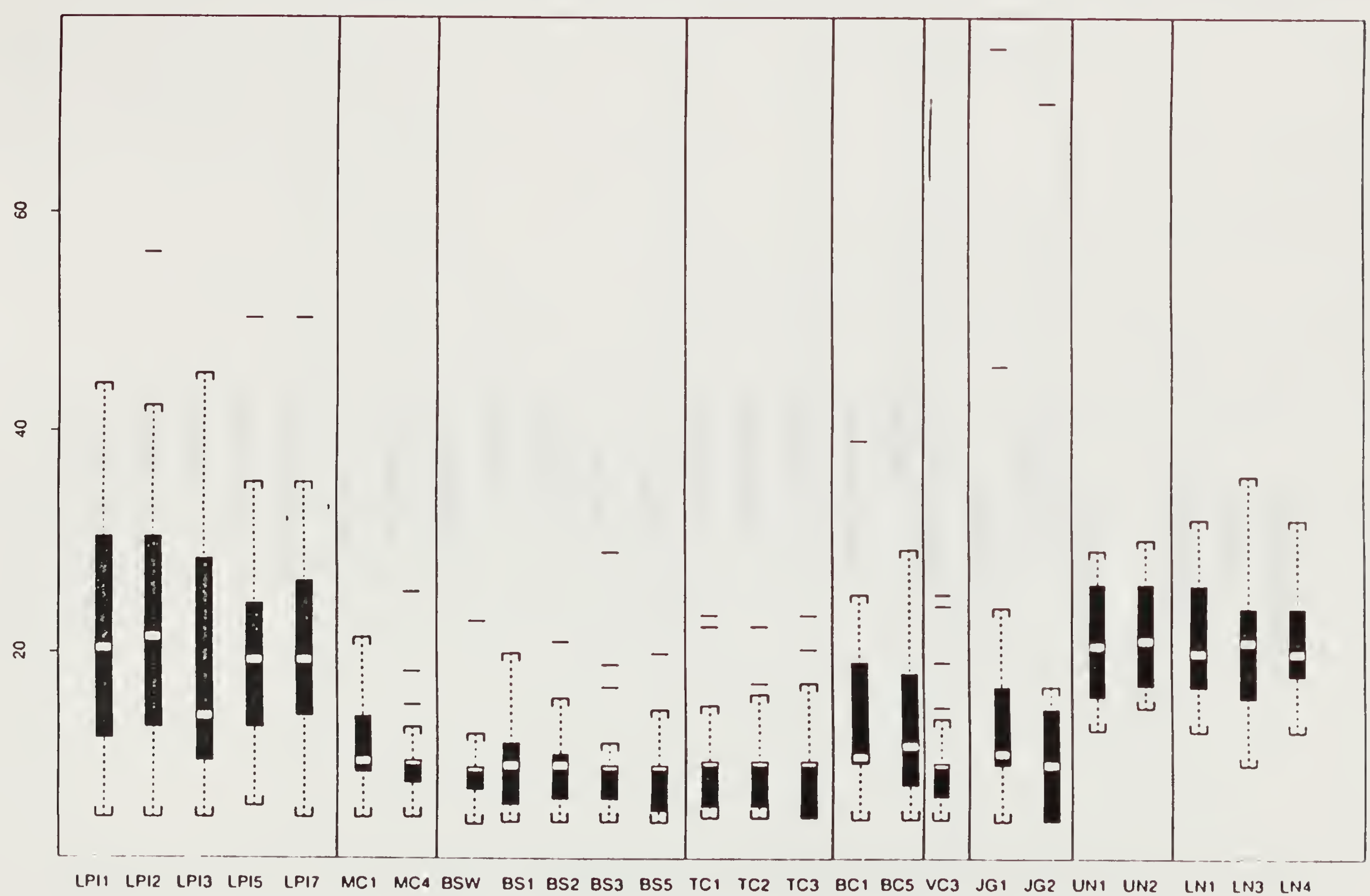


Fig. 21. Log10 Fecal Coliform/100 ml for BTNP Sample Locations

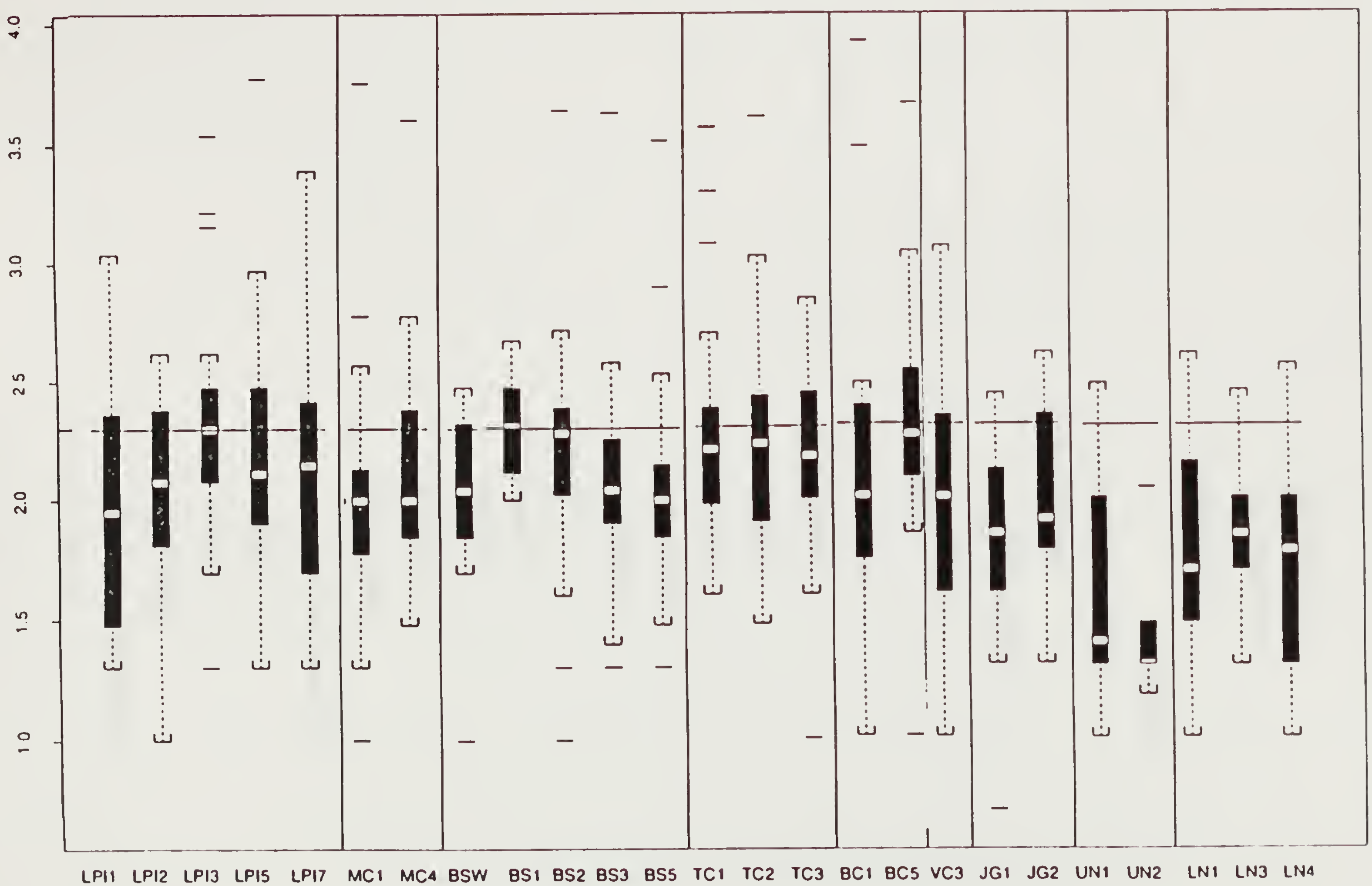


Fig. 22. Log10 Fecal Strep/100 ml for BTNP Sample Locations

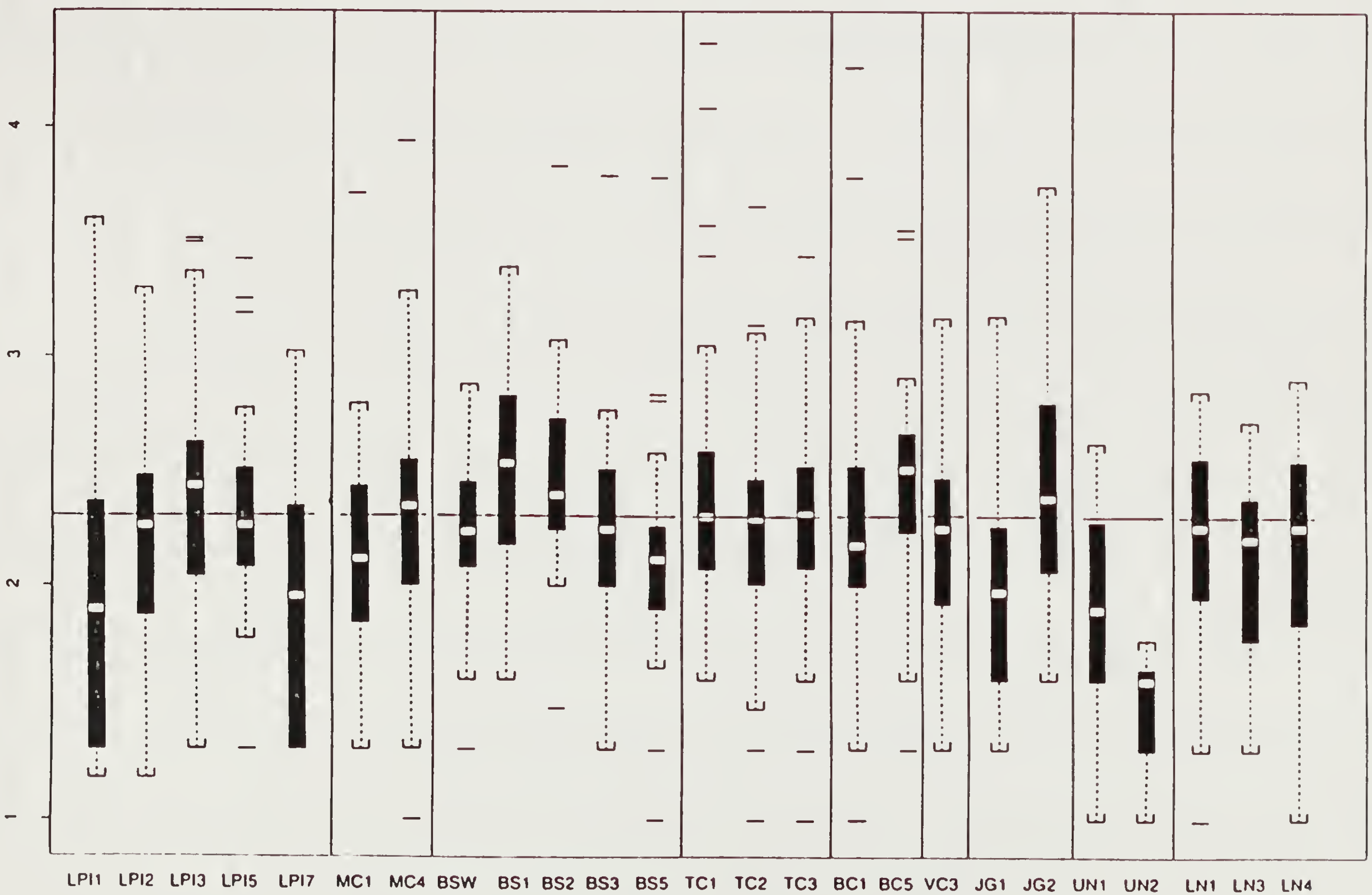


Table 7. Analysis of direction and significance of trends in all water quality parameters from Big Thicket Stations based on permutation tests. Shaded boxes indicate negative trends, unshaded boxes indicate positive trends, asterisks indicate significance of an individual trend at the 0.05 level.

SITE	Temp	Turb	pH	Diso	Cond	Sulf	TSS	Chl	Alk	TDS	Color	Fcol	Fstr
BC1	-	+	+	-	+	+*	+	+*	+	-	+	+*	+*
BC5	+	-*	+*	-	-	+*	+	-	+	-	-	+	-
BS1	+	-	+	-*	-*	+*	+*	-*	-	-	+	+*	+
BS2	+	+	+*	-*	+*	+*	+	+	-*	+	+	+	-
BS3	+	+	+*	-*	+*	+*	+*	-	-*	+	+	+	+
BS5	+	-	+*	-*	+*	+*	+	+	-	+*	+	+	+
BSW	+	+	+	-*	+	+	+*	+	-	+*	+*	+	+*
JG1	+	-	+	-*	+*	+*	+	+	+	+	-	-	-
JG2	+	-*	+*	-*	+	+	-	+	+	-*	+	+	-
LN1	-	-	+	-*	-*	-	+	-*	-*	-	+	+*	+
LN1	+	-	+	-*	-*	+	+	-*	-*	-	+*	+*	+*
LN4	+	-	-	-	-	+	-	-*	-	-	+	+*	+*
LPI1	+*	-*	+	-	-*	+	-	+	+	-	-	-	-
LPI2	+	-	+	-*	-	+*	-	+	+	+	-	+	-
LPI3	+	-*	+*	-*	-*	+*	-	-*	-	-	-	-	-
LPI5	+	-	+*	-*	-	+*	-	-	-	+	+	+	-
LPI7	+	-	+*	-*	-	+*	-	-*	-	-	+	-	+
MC1	+	-	+*	-*	-*	+*	+	-	-	+	-	+	+
MC4	+	-	+*	-*	+	+*	-	-	+	+	+	+	-
TC1	+	-	+*	-*	-	+	+	-	-	-	+	+	+
TC2	+	-	+*	-*	-	+*	+	-	+	+*	+	+	-
TC3	+	+	+*	-*	-	+	+	+	-	+	+	+	+
UN1	+	+	+	-*	+	-	+	-*	-*	-	+	+*	+*
UN2	-	-	+	-	-	-	+	-	-	-	-	-	+
VC3	-	-	+*	-*	+	+*	+	-	-	+	+	+	-

One further level of analysis used the entire set of correlation coefficients to analyze for region-wide patterns in direction of change for all parameters and stations. Under the assumption of no net regional change, one might expect that the proportion of increases (positive coefficients) to decreases (negative coefficients) would be 1:1. Assuming equal probability for positive and negative trends, and assuming independence among sample locations, the probability of various outcomes can be computed using the binomial distribution. This test is analogous to a sign test (Sokal and Rohlf 1973). Since it was unlikely that stations on the same steam were completely independent for all parameters, these calculated probabilities probably underestimated the expected frequencies, indicating more trends than were really present (e.g., there is an unknown amount of pseudoreplication (Hurlbert 1986)).

As a means of avoiding pseudoreplication due to lack of independence among stations on the same stream, the same analysis was also done for individual streams, (n=9 rather than n=25). Streams were classified an having positive or negative trends for each parameter based on the majority result for all stations on that stream. This test was extremely conservative because streams were more likely than stations to be independent from one another and because we dealt with ties in the most conservative manner possible. Where ties occurred (e.g., equal numbers of increases or decreases in stations on the same stream), the outcomes were assigned to the less frequently occurring class, unless one of the tied values was significant according to the permutation test. In that case, the tie was assigned to the class with the significant result. Recall that we were calculating the probability of rare events (many independent events with the same outcome, for instance 25 events with one outcome and 1 event with the other). Assigning ties to the less frequent class tended to force results toward the expected ratio of 1:1. Results are shown in Table 8.

The most striking long-term trend was the region-wide decline in dissolved oxygen (all 25 stations declined, 12 significantly, Table 7). The expected frequency of this pattern occurring by chance was conservatively estimated as .002 (Table 8). Possible explanations for this trend include increasing water temperature, or increased loadings of organics. There was also evidence in the dataset for a region-wide change in water temperature (22 of 25 stations had positive correlations with time). The regional pattern of an increase in water temperature was significant

based on the larger sample size, but not significant using the conservative test with the smaller sample size (Table 8). However, the dissolved oxygen results are consistent with an overall increase in water temperature. Increasing water temperature could result from land-use changes (such as forest to pasture or rural to urban), changes in the amount of shade along the watercourse, or timbering activities. It could also result from increasing air temperatures due to long-term climatic fluctuations, or to global warming. There was mixed evidence regarding an increase in organic loadings: TSS and color increased, but not significantly, while turbidity declined significantly ($p=.02$).

Another striking trend was the region-wide increase in pH (24 of 25 stations increased, 10 significantly, Table 7). Alkalinity and hardness of waters in the region is low, suggesting that the capacity of natural waters here to buffer a decline in pH is low. However, a seeming contradiction is the significant increase in sulfate and the non-significant decline in alkalinity. Neither the significant increase in sulfates nor the decline in alkalinity is consistent with an increase in pH. Increased pH in surface waters could result from agricultural practices such as liming or from aquaculture (such as catfish farming, where liming is customary to increase productivity). It could also result from algae blooms, which can increase pH by depleting CO_2 in the water column. Increasing sulfates could be the result of atmospheric deposition of pollutants. Given declining alkalinity and increasing sulfates, there is no simple explanation of the significant regional increase in pH.

Chloride concentrations declined, especially in the Lower Neches and in Little Pine Island Bayou, Menard Creek, and Turkey Creek. This is probably due to declining releases of oilfield brines and (perhaps) reduced saltwater intrusion.

Because there were many fewer USGS stations, with varying lengths of record, many fewer samples per year, and an inconsistency in variables measured, a similar analysis was done for only a few variables: water temperature, pH, alkalinity, sulfate, chloride, specific conductance and TDS (Table 9). The USGS data support the observations of increasing sulfate, declining alkalinity, and declining chloride concentrations. The decline for USGS data in specific conductance and TDS are internally consistent, and are probably related to the decline in chloride concentrations. Water temperature declined at 4 of 6 stations. While the decline was not

Table 8. Analysis of Big Thicket water quality data for regional trends. Expected frequencies were calculated using the binomial probability distribution based on proportions of stations (25) and streams (9) showing increases or decreases under the null expectation of increases and decreases being equally probable.

Parameter	Number of Stations Increasing (Significant)	Number of Stations Decreasing (Significant)	Expected Frequency n=25 Stations	Number of Streams Increasing: Decreasing	Expected Frequency n=9 Streams
Temperature	22 (1)	3 (0)	.000078	7:2	.09
Turbidity	3 (0)	22 (4)	.000078	9:0	.002
pH	24 (14)	1 (0)	.00000078	9:0	.002
DO	0 (0)	25 (20)	.00000003	0:9	.002
Specific Conductance	10 (4)	15 (6)	.212	4:5	0.5
Sulfate	22 (15)	3 (0)	.000078	8:1	.02
TSS	16 (3)	9 (0)	.115	6:3	0.25
Chloride	7(1)	18 (7)	.0216	3:6	.25
Alkalinity	7 (0)	18 (5)	.0216	2:7	.09
TDS	12 (3)	13 (1)	0.5	4:5	0.5
Color	17(2)	8 (0)	.054	5:4	0.5
Fecal Coliform	19 (6)	6 (0)	.0073	7:2	.09
Fecal Strep-tococcus	17 (5)	8 (0)	.054	5:4	0.5

Table 9. Analysis of direction and significance of trends in selected water quality parameters from USGS Stations based on permutation tests. Shaded boxes indicate negative trends, unshaded boxes indicate positive trends, double asterisks indicate significance of an individual trend at the 0.01 level.

Station	08040500 Steinhagen Lake	08040600 Neches River @ Town Bluff	08041000 Neches River @ Evadale	08041500 Village Creek	08041700 Pine Island Bayou	08066300 Menard Creek
Temp	-	-	-	+	-	-
pH	-	+	+	-**	-**	-
Alkalinity	-	-	-**	+	-**	-**
Sulfate	-	-	+**	+**	+	+**
Chloride	-	-	-**	-**	-**	-**
Spec. Conduct.	-	-	-**	-**	-**	-**
Dissolved Solids	-	-	-**	-**	-**	-**

regionally significant, it did not support the BTNP observations of increasing water temperature.

The regional increase in temperature and decline in DO levels may also be related to change in instrumentation. After these regional trends were detected, the possibility that these changes were simply related to a change in instrumentation and sampling protocol was raised. In late 1991, Big Thicket began to use a Hydrolab H-20 instrument in place of their older equipment. In the summer of 1995, NPS and Rice personnel conducted a small study where a number of stations were sampled with both the old and the new equipment. Consistent differences suggest that the change in protocol and instrumentation may account for the regional patterns in temperature, DO, and pH. Correction of long-term data to account for this change would require further study and development of year-round correction factors.

Summary

Overall indications are that regional water quality has declined somewhat, with the exception of declines in turbidity and chloride concentrations. The regional decline in dissolved oxygen is particularly troubling, as is the increase in pH. However, certain contradictions in the structure of the regional trends are also troubling (the sulfate-pH-alkalinity relationship). A change in sampling protocol may explain at least some of the regional trends. Both BTNP and USGS data suggest increasing sulfate concentrations, declining alkalinity and declining chloride concentrations.

IDENTIFICATION OF POTENTIAL WATER QUALITY PROBLEMS

The purpose of this chapter is to identify potential water quality problems which should be considered and addressed as part of the Water Corridor Management Plan. In addition to enumerating specific water quality problems identified earlier in this report or by other authors, we will also attempt to identify data gaps, and to suggest possible sources of additional information. The water quality sampling program of the BTNP is also evaluated.

Areas of concern for water quality as reported in the SB818 report

The SB818 report (Alan Plummer and Associates 1992) characterizes the water quality of the Lower Neches River Basin. We have extracted information from this report pertaining to the Big Thicket National Preserve Units of the Water Corridor Management Program (Segments 602, 607, & 608) and it is summarized below.

<u>Lower Neches River (below Steinhagen Dam), Segment 602</u>

This segment is 88 miles long. It is sparsely populated (26,912 in the 1990 census). In 1977, 54% of the area was forest land, 31% wetland, 13% unirrigated cropland and 3% urban. Its designated uses (a state designation for each watercourse which determines which water quality criteria are applied) include contact recreation, high quality aquatic habitat, and public water supply.

Several areas of concern were identified for this segment including contamination by fecal coliform bacteria, low DO, exceedances of the standards for a number of heavy metals, and possible toxics from industrial effluent (Alan Plummer and Associates, 1992). Investigations by the TWC in 1992 found that fecal coliform levels exceeded the 200/100ml criteria 11% of the time. The presence of high counts of fecal coliform bacteria, which indicates sewage contamination, is of concern because of the large number of residences which rely on individual septic systems (estimated 2,195 in the basin in 1980). Consistent high values suggest that the septic systems are not adequately treating sewage from individual residences and that better regulation, inspection, and maintenance may be required to meet the standard, or that the

development of regional wastewater treatment systems should be made a higher priority. As of 1992, there were five permitted wastewater dischargers (2 municipal permits and 3 industrial). Permitted municipal wastewater discharges totalled 1.007 MGD.

Preliminary surveys of recent Texas Water Commission (TWC) and U.S. Geological Survey (USGS) data showed dissolved oxygen (DO), pH, fecal coliform, zinc, copper, cadmium and lead levels in exceedance of water quality criteria. Saltwater intrusions during periods of drought were identified as a chronic problem, often dealt with by the use of temporary saltwater barriers. Another potential problem was from bleached kraft pulp and paper mills on the lower portion of this segment. In 1990, the U.S. Environmental Protection Agency (EPA) found concentrations of the dioxin, 2,3,7,8-TCDD (a by product of the bleaching process in paper production), in spotted gar. This led the Texas Department of Health (TDH) to issue a consumption warning which is still in effect.

The SB818 report was revised in 1994 (Alan Plummer and Associates, 1994) and the list of current management concerns was reduced. Currently, only cadmium and zinc remain among the previously listed heavy metals as areas of concern due to infrequent sampling and unreliable sampling results. The TDH advisory is still in effect for dioxin contamination, but this was not cited in the current assessment. Fecal coliform, DO and pH were not cited as current concerns, since the frequency of violations of criteria for these parameters was less than 10% since 1985. Saltwater intrusion remains an area of concern.

<u>Pine Island Bayou, Segment 607</u>

This segment is 81 miles long with a population of 37,941 (1990 census). In 1977, about 71% of the area was forest land, 20% irrigated cropland, 4% unirrigated cropland and 3% urban. Its designated uses include contact recreation, high quality aquatic habitat, and public water supply.

In 1978, the TWC Intensive Survey cited low DO as a frequent, although naturally occurring problem (result of low flow in summer). However, the mid-26 miles of the segment, downstream from the Sour Lake wastewater discharge did not support high quality aquatic life due to depressed DO. A 1983 Lower Neches Valley Authority (LNVA) study found fecal coliform levels in exceedence of the 200/100ml criteria. In 1978, 4,745 residences in the

watershed relied on individual septic systems. As of 1992, there were eight permitted wastewater dischargers (all municipal permits, with no industrial dischargers). Total permitted municipal flow was 3.168 MGD.

Brines from the numerous oil and gas fields, *e.g.*, Saratoga, Sour Lake, Batson, were identified as contributing to a recurring problem with elevated chlorides in this segment. The 1978 TWC Intensive Survey indicated elevated levels of arsenic, manganese, and mercury in the sediment. Preliminary screening of recent TWC and USGS data revealed DO, pH , and fecal coliform as potential problems (Alan Plummer and Associates, 1992).

The 1994 basinwide assessment of water quality (Alan Plummer and Associates, 1994) found no exceedances for chloride since 1985, but only 16 measurements. DO concentrations were carried forward as a continuing concern, and phosphorus loadings were identified as a new problem. Fecal coliform continued to be identified as a problem, while pH values violated criteria levels in only 2% of measurements.

<u>Village Creek, Segment 608</u>

This segment is 53 miles long with a population of 39,440 (1990 census). Most of the area is forest land with the remainder unirrigated cropland. Less than 2% is urban area. Its designated uses include contact recreation, high quality aquatic habitat, and public water supply.

TWC tests made from 1987-91 found no parameters outside of the water criteria. Preliminary screening of recent TWC and USGS data reveal DO and pH as potential problems. In 1978, 3,789 residences of the Village Creek watershed relied on individual septic systems. Areas of concentrated septic tank usage include north part of Lumberton, area north of Silsbee, Honey Island, Village Mills, Hillister and Doucette. Silsbee, Kountze and Woodville have wastewater treatment facilities. As of 1992, there were sixteen permitted wastewater dischargers (ten municipal permits and six industrial dischargers). Total permitted municipal flow was 2.034 MGD and industrial flows were reported as 0.3698 MGD.

The 1994 basinwide assessment of water quality (Alan Plummer and Associates, 1994) continued to list fecal coliform and pH as problem areas. DO concentrations were not carried forward as a continuing concern. Aluminum concentrations were identified as a new problem, although the report suggested that high concentrations might be natural.

Nonpoint sources

The previous sections have dealt with permitted point-source discharges. There are also several possible nonpoint sources of pollution in the area. Urban stormwater run-off can include fecal coliform, nutrients, toxins, floatables, and oxygen demanding substances. Table II-2 in the SB818 report (Alan Plummer and Associates, 1992) lists annual pollutant loads for 1990-95 in this basin as estimated during the 208 planning process in 1977. While these estimates are very old, no newer estimates were available.

Agricultural run-off can carry oxygen-demanding substances, suspended solids, nutrients and toxins. In southeast Texas, there is a potential nonpoint-source pollution problem from biocides associated with runoff from agricultural fields, primarily rice and soybeans. A study funded by the Texas State Soil and Water Conservation Board (McCauley, 1993) found that best management practices (BMP, such as shallower flooding depths, precision contouring, and the use of multiple inlets) combined with the integrated pest management plan (IPM, as outlined in the Texas Agricultural Extension Rice Production Guidelines) resulted in reduced concentrations of fertilizers and biocides in runoff. Nitrogen runoff was found to be between 6.54-24.83 lb./acre, averaging 10.54 lb. /acre. This was high compared to estimated runoff from East Texas pine forests (3 lb. /acre) but low compared to improved pasture (15 lb./acre) and irrigated row crops (25-35 lb./acre). The authors concluded that following BMP resulted in enhanced retention of most of the applied chemicals on the rice fields.

The SB818B report (Alan Plummer and Associates, 1992) showed no biocide levels in exceedence of water quality criteria. Although concentrations of biocides in water in the Lower Neches met all standards, USGS data (summary shown in appendix) showed many biocide concentrations in sediments (bottom material) in exceedence of the standards for water in the Lower Neches. There are no standards for sediment concentrations.

Other sources of non-point source pollution include oilfields, septic tanks, dredging, and harvesting of trees. Brines entering as runoff have frequently caused elevated levels of chlorides, especially in Little Pine Island Bayou and Menard Creek. The major pollutants associated with septic tank systems are fecal coliform, oxygen demanding substances and nutrients. Hydrologic and habitat modification activities (*e.g.*, channelization) may result in such pollutants as oxygen

demanding substances, suspended solids, toxins and nutrients. Also, changes in canopy cover can alter water temperature.

Areas of concern for Big Thicket water quality as identified in this report

In the previous chapter, we identified several long-term trends in BTNP data which should be monitored: declining dissolved oxygen, increasing pH, declining alkalinity and increasing sulfate concentrations. Continued monitoring and assessment of these parameters should be part of continuing management. Still, these data were not included in the regional screening procedure in the SB818 report. As a means of identifying water quality problems in the BTNP, we screened all measured water quality parameters for which standards exist within the region. For convenience, a single screening value was adopted for each parameter. By convention, we adopted for each parameter the most conservative standard for any stream in the region (Table 10). Low dissolved oxygen was a regional problem (Table 11). Most of the pH excursions were for low pH (BC and JG sites), although some were for high values. Overall, the Little Pine Island Bayou watershed had the worst water quality in the region throughout its length. Identified problems included DO, fecal coliform, sulfate concentrations, chloride concentrations and TDS. Turkey Creek also had some problems with fecal coliform, and the upper Neches sites had high TDS.

Evaluation of BTNP Water Quality Sampling Program

The water quality sampling program of the BTNP has been very comprehensive and the effort is commendable. Overall, these data could be important to management and decision-making both for the BTNP and for other agencies. Compared to other agencies (e.g., USGS and TNRCC), the frequency of sampling was high and probably adequate to detect potential problems. Spatial coverage was also very high compared to USGS and TNRCC.

We have identified some problems with the program which should be addressed to increase the value and reliability of the data. First, the spatial coverage has declined since the inception of the program. The spatial completeness of the dataset is one of its major strengths.

Table 10. Screening values for Big Thicket area streams as presented in Plummer et al., 1994, along with composite standard used for screening all BTNP streams in this report.

Parameter	Pine Island Bayou	Village Creek	Neches River at Evadale	Composite Standard
Fecal Coliform	>400	>400	>400	>400
DO	<5	<5	<5	<5
pH	6–8.5	6–8.5	6–8.5	6–8.5
Sulfate	>50	>75	>30	>30
Chloride	>150	>150	>50	>50
Temperature	>35	>32.2	>32.7	>32.2
TDS	>300	>300	>150	>150

Table 11. Screening results for BTNP stations using approximate SB818 screening values for selected parameters. Parameters are indicated if 10% or more of all observations fell outside the screening range.

Site	Temp	pH	Diso	Fecol	Sulf	Chlor	TDS
BC1		Out	Low				
BC1		Out	Low	High			
BS1			Low				
BS1			Low				
BS1			Low				
BS3			Low				
BS5			Low				
BSW		Out	Low				
JG2		Out	Low		High		
JG2		Out	Low				
LN1			Low				
LN3			Low				
LN1			Low				
LPI2		Out	Low	High	High	High	High
LPI2		Out	Low		High	High	High
LPI3			Low	High	High	High	High
LPI5			Low	High	High	High	High
LPI7			Low	High	High		High
MC1			Low				
MC4			Low				
TC1			Low	High			
TC2			Low				
TC3			Low	High			
UN1							High
UN2			Low				High
VC3		Out	Low	High			

For the dataset to be most useful, the decline in spatial coverage should not be allowed to continue. Since the Village Creek Corridor will soon be added to the Preserve, some thought should be given to increasing the number of stations on this watercourse (there is only one currently). Additionally, since the focus of the initial sampling was on the smaller streams, the Neches River stations were sampled less frequently while they were sampled and are not now currently being sampled. Since so much of the Preserve borders the Neches, sampling at these stations should be reinstituted and frequency should be increased to monthly to allow comparisons to all other stations (which are currently sampled monthly). BTNP should also consider whether to refocus the sampling program so that the water corridors could be better characterized.

The major problems with the BTNP program involve issues of quality control, data management, and documentation. Most procedures were documented early in the program, but the procedures manuals have not been adequately updated or maintained to reflect changes in instruments or protocol. No procedures have been implements to test, document, or correct for such changes.

There is currently no procedure for routine data entry and analysis of the data. While data have been entered sporadically in the past, we found much missing data from computer files that had never been entered. Additional problems include inadequate proofreading of entered data, and inconsistent coding standards for certain values. For instance, in some years, missing values were entered as zeros, but not for all years. Some unique coding should be assigned to missing values which is not numeric. When summaries are made of data, using either spreadsheets or statistical software, missing values are usually ignored, while zeros are treated as data points and added to averages or used in calculations of median values. This will lead to erroneous results.

Problems in data entry included inconsistency about which values on raw data sheets should be entered into which columns of the spreadsheets. Confusion about the names of stations has arisen over time, primarily because not all stations initially identified were sampled and station names were confusing. For example, on Big Sandy, the stations BS1, BS2, BS3, BS5, and BSW were included in the program. In the computer database and on original field sheets, BS5 was sometimes mis-identified as BS4, which was not ever sampled. BSW was in one case then mis-identified as BS-5.

Changes in instrumentation have occurred which were undocumented or poorly documented. For instance, a change in instrumentation and protocol at some time during the last decade no longer allows for field (in situ) water temperatures to be measured. Sample temperatures have always been measured at the vehicle as part of the DO measurement. At some point, sample water temperatures were substituted for field temperatures. It is not clear what the effects of this change have been on the record, although it would be possible to assess this with some data not currently entered in the computer data base. In another case, in December of 1985, the NPS was evidently considering a change of pH meter. For that month, pH and temperature were measured twice, once with each meter (Orion and Beckman). However, no subsequent documentation of the change was ever made, although there appeared to have been some systematic differences between the two. Certainly for the purposes of quality control, double sampling should occur for a year prior to any change in instrumentation. Methods and frequency of instrument calibration should also be well documented and frequent calibration should be implemented.

Finally, toward the end of the decade, consistency in the time of sampling as well as the frequency of sampling declined. Consistency of the timing of sampling is critical to the use of such methods as time series analysis for the analysis of trends. Time series analysis requires regular sampling because it assumes a uniform time step between samples. While we wished to use some time series methods in analyzing these data for trend, lack of conformity to a regular sampling schedule and numerous missing values required the use of other methods (e.g., the permutation tests).

There is no formal quality assurance/quality control (QA/QC) program associated with this water quality sampling program. Lack of such a program reduces the value and the reliability of otherwise unique and valuable datasets like these. Furthermore, when outside laboratories are utilized, regular information about their compliance with federal QA/QC programs should be obtained by BTNP. To increase the usefulness of the data, an in-house QA/QC program should be designed and implemented for the water sampling program.

Summary and Conclusions

While the SB818 report for 1994 did not list low DO as a continuing problem for all three segments (only for Pine Island Bayou, not for Village Creek or the Neches River below Steinhagen Lake), our review of the data suggests that DO could be declining regionally, and that low DO should be of current concern region-wide. Little Pine Island Bayou has the worst water quality in the region; the DO standards were exceeded more than 10% of the time. While chlorides are still high, there has clearly been some improvement in Little Pine Island Bayou with respect to chlorides, presumably from reduced contamination by oilfield brines. However, fecal coliform levels, sulfate concentrations, and TDS remain high.

The trend analyses indicated that regional water quality declined somewhat over the decade, with the exception of a significant improvement in turbidity. The regional decline in dissolved oxygen is particularly troubling, given the importance of DO as an element of high-quality aquatic habitat. Also troubling is the increase in pH. However, certain contradictions in the structure of the regional trends are also troubling (the sulfate-pH-alkalinity relationship), and we have no ready explanation for these apparent contradictions. A lack of a QA/QC program associated with Big Thicket National Preserve's water quality sampling program may have reduced its value as a source of long-term data and casts some doubt on the significance of the long-term trend analysis.

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Appendix A

Summary of Data for USGS Stations

Appendix A

Summary of Data for USGS Stations

		STATION					
		08040500-Steinnagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
WATER TEMPERATURE	MEAN	21.06	20.62	21.02	19.37	20.49	19.65
	MIN	8.00	12.50	6.00	4.00	3.00	6.00
	MAX	31.00	28.50	32.00	35.50	34.00	29.50
	N	51.00	12.00	214.00	106.00	130.00	193.00
DISCHARGE	MEAN	.	.	4724.58	713.10	288.43	172.04
	MIN	.	.	38.00	26.00	1.90	5.20
	MAX	.	.	24100.00	5840.00	2620.00	5410.00
	N	0.00	0.00	91.00	89.00	147.00	47.00
DISCHARGE, INST.	MEAN	5523.73	9286.67	7566.22	1062.23	718.25	160.40
	MIN	1710.00	2380.00	155.00	61.00	1.00	11.00
	MAX	21700.00	17400.00	38100.00	11700.00	15200.00	2350.00
	N	51.00	12.00	180.00	91.00	142.00	151.00
GAGE HEIGHT	MEAN	55.62	.	10.99	6.65	16.49	9.70
	MIN	50.66	.	6.73	2.00	11.78	7.60
	MAX	69.61	.	18.21	19.04	32.06	16.10
	N	48.00	0.00	47.00	23.00	46.00	64.00
TURBIDITY(JACKSON CANDLE UNITS)	MEAN	.	.	35.69	.	.	.
	MIN	.	.	15.00	.	.	.
	MAX	.	.	150.00	.	.	.
	N	0.00	0.00	72.00	0.00	0.00	0.00
TURBIDITY (NTU)	MEAN	18.66	.	24.96	.	.	.
	MIN	3.60	.	1.80	.	.	.
	MAX	38.00	.	60.00	.	.	.
	N	33.00	0.00	96.00	0.00	0.00	0.00
COLOR	MEAN	53.33	.	90.31	.	.	.
	MIN	10.00	.	20.00	.	.	.
	MAX	150.00	.	240.00	.	.	.
	N	33.00	0.00	103.00	0.00	0.00	0.00
SPECIFIC CONDUCTANCE	MEAN	155.08	125.83	157.94	104.30	325.06	159.99
	MIN	109.00	92.00	67.00	31.00	32.00	44.00
	MAX	213.00	145.00	235.00	237.00	11600.00	957.00
	N	51.00	12.00	277.00	181.00	285.00	203.00
OXYGEN DISSOLVED	MEAN	9.51	8.89	8.53	.	.	.
	MIN	6.60	6.40	4.70	.	.	.

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
OXYGEN DISSOLVED	MAX	14.10	12.50	13.20	.	.	.
	N	50.00	12.00	192.00	0.00	0.00	0.00
OXYGEN DIS. PERCENT	MEAN	104.50	96.11	93.30	.	.	.
	MIN	80.00	80.59	11.20	.	.	.
	MAX	132.09	115.30	119.00	.	.	.
	N	50.00	12.00	190.00	0.00	0.00	0.00
BOD 5-DAY AT 20 DEG	MEAN	1.32	0.98	1.40	.	.	.
	MIN	0.50	0.20	0.00	.	.	.
	MAX	3.50	1.70	8.00	.	.	.
	N	50.00	12.00	192.00	0.00	0.00	0.00
COD LOW LEVEL (MG/L)	MEAN	.	.	24.55	.	.	.
	MIN	.	.	11.00	.	.	.
	MAX	.	.	39.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00
PH, FIELD	MEAN	6.93	6.96	6.82	6.22	6.84	6.26
	MIN	6.20	6.30	5.90	4.80	5.80	5.30
	MAX	7.60	7.50	8.20	7.60	7.80	7.90
	N	51.00	12.00	277.00	138.00	226.00	105.00
PH, LABORATORY	MEAN	7.44	7.29	7.28	6.91	7.27	6.98
	MIN	6.10	6.90	5.30	5.60	6.20	5.30
	MAX	8.30	7.60	8.50	7.80	9.80	7.90
	N	51.00	12.00	79.00	36.00	50.00	90.00
CARBON DIOXIDE DISS.	MEAN	.	.	9.55	15.81	10.44	14.29
	MIN	.	.	0.70	0.00	0.90	0.30
	MAX	.	.	48.00	51.00	50.00	72.00
	N	0.00	0.00	102.00	53.00	85.00	58.00
ALKALINITY,-WH,FET,F	MEAN	17.20	17.83	20.62	8.85	32.64	10.24
	MIN	9.00	15.00	6.00	1.00	7.00	2.00
	MAX	24.00	21.00	48.00	20.00	90.00	26.00
	N	51.00	12.00	260.00	181.00	283.00	203.00
BICARBONATE-,WH,FET,F	MEAN	.	.	26.69	10.70	41.03	12.85
	MIN	.	.	10.00	0.00	8.00	4.00
	MAX	.	.	58.00	20.00	110.00	32.00
	N	0.00	0.00	182.00	145.00	233.00	113.00

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
CARBONATE,W-H,FET,F	MEAN	.	.	0.00	0.00	0.00	0.00
	MIN	.	.	0.00	0.00	0.00	0.00
	MAX	.	.	0.00	0.00	0.00	0.00
	N	0.00	0.00	183.00	145.00	233.00	113.00
CARBONATE,W-H,IT,F	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	5.00	0.00	0.00	0.00
BICARBONATE-,WH,IT,F	MEAN	.	.	21.40	.	.	.
	MIN	.	.	18.00	.	.	.
	MAX	.	.	25.00	.	.	.
	N	0.00	0.00	5.00	0.00	0.00	0.00
CARBONATE,D-IS,IT,F	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
BICARBONATE-,DIS,IT,F	MEAN	.	.	19.48	.	.	.
	MIN	.	.	14.00	.	.	.
	MAX	.	.	26.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
RESIDUE TOTAL LOSS ON IGN	MEAN	.	.	15.29	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	30.00	.	.	.
	N	0.00	0.00	7.00	0.00	0.00	0.00
RESIDUE TOTAL NON FILT	MEAN	25.72	.	55.66	.	.	.
	MIN	4.00	.	13.00	.	.	.
	MAX	178.00	.	124.00	.	.	.
	N	32.00	0.00	98.00	0.00	0.00	0.00
RESIDUE VOLATILE	MEAN	8.31	.	15.13	.	.	.
	MIN	0.00	.	0.00	.	.	.
	MAX	43.00	.	43.00	.	.	.
	N	32.00	0.00	91.00	0.00	0.00	0.00
RESIDUE FIXED	MEAN	17.63	.	40.46	.	.	.
	MIN	0.00	.	1.00	.	.	.

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
RESIDUE FIXED	MAX	135.00	.	104.00	.	.	.
	N	30.00	0.00	91.00	0.00	0.00	0.00
BIOMASS, PERIPHYTON	MEAN	.	.	11.82	.	.	.
	MIN	.	.	1.50	.	.	.
	MAX	.	.	30.20	.	.	.
	N	0.00	0.00	7.00	0.00	0.00	0.00
BIOMASS PERIPHYTON TDW	MEAN	.	.	18.44	.	.	.
	MIN	.	.	3.40	.	.	.
	MAX	.	.	35.80	.	.	.
	N	0.00	0.00	5.00	0.00	0.00	0.00
NITROGEN TOTAL	MEAN	0.71	0.87	0.77	.	0.77	.
	MIN	0.50	0.51	0.13	.	0.77	.
	MAX	0.90	1.23	1.78	.	0.77	.
	N	5.00	2.00	89.00	0.00	1.00	0.00
NITROGEN DISSOLVED	MEAN	.	.	0.65	.	.	.
	MIN	.	.	0.38	.	.	.
	MAX	.	.	1.42	.	.	.
	N	0.00	0.00	23.00	0.00	0.00	0.00
NITROGEN ORGANIC TOT	MEAN	0.64	0.51	0.60	.	0.70	.
	MIN	0.00	0.26	0.03	.	0.70	.
	MAX	1.69	1.07	2.02	.	0.70	.
	N	47.00	11.00	142.00	0.00	1.00	0.00
NITROGEN ORGANIC DIS	MEAN	.	.	0.52	.	.	.
	MIN	.	.	0.20	.	.	.
	MAX	.	.	1.04	.	.	.
	N	0.00	0.00	23.00	0.00	0.00	0.00
NITROGEN AMMONIA DIS	MEAN	.	.	0.05	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.28	.	.	.
	N	0.00	0.00	88.00	0.00	0.00	0.00
NITROGEN AMMONIA TOT	MEAN	0.07	0.05	0.05	.	0.02	.
	MIN	0.01	0.01	0.00	.	0.02	.
	MAX	0.88	0.18	0.46	.	0.02	.
	N	51.00	12.00	150.00	0.00	1.00	0.00

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
NITROGEN,NITRITE DIS	MEAN	.	.	0.01	.	.	.
	MIN	.	.	0.01	.	.	.
	MAX	.	.	0.03	.	.	.
	N	0.00	0.00	42.00	0.00	0.00	0.00
NITROGEN,NITRITE TOT	MEAN	0.02	0.02	0.01	.	0.01	.
	MIN	0.00	0.01	0.00	.	0.01	.
	MAX	0.07	0.04	0.04	.	0.01	.
	N	51.00	12.00	102.00	0.00	1.00	0.00
NITROGEN NITRATE D.	MEAN	.	.	0.08	0.00	.	0.00
	MIN	.	.	0.05	0.00	.	0.00
	MAX	.	.	0.13	0.00	.	0.00
	N	0.00	0.00	4.00	5.00	0.00	5.00
NITROGEN NITRATE T.	MEAN	0.06	0.09	0.08	0.07	0.58	0.10
	MIN	0.00	0.07	0.00	0.00	0.04	0.00
	MAX	0.17	0.10	0.50	0.40	4.00	0.40
	N	5.00	2.00	141.00	39.00	81.00	42.00
NITRO AMN & ORG DIS	MEAN	.	.	0.66	.	.	.
	MIN	.	.	0.17	.	.	.
	MAX	.	.	3.30	.	.	.
	N	0.00	0.00	41.00	0.00	0.00	0.00
NITROGEN SUSPENDED	MEAN	.	.	0.30	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	1.00	.	.	.
	N	0.00	0.00	28.00	0.00	0.00	0.00
NITROGEN AMM+ORG TOT	MEAN	0.69	0.56	0.73	.	0.72	.
	MIN	0.40	0.30	0.08	.	0.72	.
	MAX	1.80	1.10	3.00	.	0.72	.
	N	51.00	12.00	149.00	0.00	1.00	0.00
NO2 + NO3 TOTAL	MEAN	0.10	0.10	0.06	.	0.05	.
	MIN	0.00	0.05	0.00	.	0.05	.
	MAX	0.50	0.13	0.23	.	0.05	.
	N	50.00	12.00	95.00	0.00	1.00	0.00
NO2 + NO3 DISSOLVED	MEAN	.	.	0.09	.	.	.
	MIN	.	.	0.00	.	.	.

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
NO2 + NO3 DISSOLVED	MAX	.	.	0.44	.	.	.
	N	0.00	0.00	88.00	0.00	0.00	0.00
PHOSPHATE TOTAL	MEAN	.	0.12	0.08	.	.	.
	MIN	.	0.06	0.00	.	.	.
	MAX	.	0.18	0.24	.	.	.
	N	0.00	4.00	35.00	0.00	0.00	0.00
PHOSPHATE ORTHO. DIS	MEAN	.	.	0.07	.	.	.
	MIN	.	.	0.03	.	.	.
	MAX	.	.	0.31	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
PHOSPHORUS TOTAL	MEAN	0.06	0.07	0.06	.	0.05	.
	MIN	0.01	0.03	0.01	.	0.05	.
	MAX	0.87	0.28	0.20	.	0.05	.
	N	50.00	12.00	177.00	0.00	1.00	0.00
PHOSPHORUS DISS.	MEAN	.	.	0.03	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.13	.	.	.
	N	0.00	0.00	107.00	0.00	0.00	0.00
PHOSPHORUS ORTHO D	MEAN	.	.	0.02	.	.	.
	MIN	.	.	0.01	.	.	.
	MAX	.	.	0.10	.	.	.
	N	0.00	0.00	67.00	0.00	0.00	0.00
CARBON ORGANIC TOT.	MEAN	7.47	.	10.48	.	.	.
	MIN	0.10	.	3.20	.	.	.
	MAX	14.00	.	41.00	.	.	.
	N	33.00	0.00	76.00	0.00	0.00	0.00
CARBON ORGANIC DIS.	MEAN	.	.	7.29	.	.	.
	MIN	.	.	5.20	.	.	.
	MAX	.	.	12.00	.	.	.
	N	0.00	0.00	15.00	0.00	0.00	0.00
CARBON ORGANIC S.	MEAN	.	.	0.88	.	.	.
	MIN	.	.	0.40	.	.	.
	MAX	.	.	1.90	.	.	.
	N	0.00	0.00	13.00	0.00	0.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
HARDNESS TOTAL	MEAN	31.27	27.88	32.64	17.54	51.26	25.82
	MIN	23.50	22.83	14.27	7.01	10.21	11.30
	MAX	40.38	31.76	53.96	26.22	576.83	117.94
	N	51.00	12.00	259.00	181.00	283.00	203.00
NONCARBONATE HARD.	MEAN	12.87	.	11.88	8.76	18.72	19.55
	MIN	7.00	.	0.00	1.00	0.00	5.00
	MAX	23.00	.	31.00	20.00	542.00	108.00
	N	15.00	0.00	200.00	161.00	245.00	133.00
CALCIUM DISSOLVED	MEAN	7.40	6.83	8.16	4.94	15.80	7.48
	MIN	5.60	5.80	3.00	1.80	3.10	3.20
	MAX	9.90	8.10	16.00	8.10	165.00	37.00
	N	51.00	12.00	259.00	181.00	277.00	196.00
MAGNESIUM DISSOLVED	MEAN	3.10	2.62	2.97	1.26	2.71	1.61
	MIN	1.40	1.90	1.00	0.10	0.40	0.50
	MAX	4.00	3.10	5.20	3.00	40.00	6.20
	N	51.00	12.00	259.00	181.00	277.00	196.00
SODIUM DISSOLVED	MEAN	16.63	12.57	15.42	12.13	41.89	15.54
	MIN	11.00	8.10	5.40	3.50	3.60	4.20
	MAX	25.00	15.00	28.00	35.00	2350.00	135.00
	N	51.00	12.00	191.00	140.00	199.00	154.00
SODIUM ADSORPTION R.	MEAN	1.29	1.03	1.21	1.21	2.20	1.46
	MIN	0.95	0.74	0.49	0.10	0.20	0.30
	MAX	1.74	1.18	2.10	3.13	42.58	5.41
	N	51.00	12.00	256.00	176.00	277.00	191.00
SODIUM, PERCENT	MEAN	50.78	46.26	49.16	56.78	55.64	55.69
	MIN	44.40	40.13	30.88	6.40	31.78	33.24
	MAX	58.23	49.25	65.00	76.00	90.00	73.00
	N	51.00	12.00	220.00	155.00	234.00	170.00
SODIUM+POTASSIUM DIS	MEAN	.	.	17.61	11.36	46.19	29.18
	MIN	.	.	4.50	1.10	2.50	3.20
	MAX	.	.	28.00	19.00	200.00	110.00
	N	0.00	0.00	76.00	43.00	87.00	46.00
POTASSIUM DISSOLVED	MEAN	2.80	2.77	2.71	1.16	2.27	1.13
	MIN	2.20	2.00	1.00	0.80	0.90	0.70

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
POTASSIUM DISSOLVED	MAX	3.60	3.60	4.70	4.30	4.90	3.10
	N	51.00	12.00	170.00	89.00	134.00	142.00
CHLORIDE DISSOLVED	MEAN	20.00	15.68	20.69	22.07	70.53	38.17
	MIN	11.00	9.30	6.00	5.90	2.40	6.90
	MAX	31.00	22.00	38.00	63.00	3980.00	283.00
	N	51.00	12.00	259.00	181.00	282.00	202.00
SULFATE DISSOLVED	MEAN	23.22	16.58	18.27	4.17	12.26	4.71
	MIN	15.00	12.00	5.00	0.20	0.60	0.00
	MAX	35.00	22.00	33.00	11.00	40.00	28.00
	N	51.00	12.00	259.00	181.00	279.00	195.00
FLUORIDE DISSOLVED	MEAN	0.12	0.12	0.11	0.09	0.14	0.08
	MIN	0.00	0.10	0.00	0.00	0.00	0.00
	MAX	0.20	0.20	0.50	0.40	0.50	0.20
	N	51.00	12.00	239.00	145.00	212.00	187.00
SILICA DISSOLVED	MEAN	10.36	9.38	9.97	11.30	6.57	11.83
	MIN	7.00	7.20	0.00	2.00	0.00	0.40
	MAX	15.00	14.00	20.00	16.00	20.00	20.00
	N	51.00	12.00	259.00	180.00	279.00	195.00
ARSENIC DISSOLVED	MEAN	0.90	1.00	0.95	.	.	.
	MIN	0.00	1.00	0.00	.	.	.
	MAX	1.00	1.00	2.00	.	.	.
	N	21.00	4.00	80.00	0.00	0.00	0.00
ARSENIC SUSPENDED	MEAN	.	.	1.06	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	2.00	.	.	.
	N	0.00	0.00	16.00	0.00	0.00	0.00
ARSENIC TOTAL	MEAN	.	.	1.71	.	.	.
	MIN	.	.	1.00	.	.	.
	MAX	.	.	3.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
BARIUM DISSOLVED	MEAN	51.48	40.75	56.53	.	.	.
	MIN	30.00	37.00	31.00	.	.	.
	MAX	200.00	43.00	300.00	.	.	.
	N	21.00	4.00	64.00	0.00	0.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
BARIUM SUSPENDED	MEAN	.	.	54.44	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	200.00	.	.	.
	N	0.00	0.00	18.00	0.00	0.00	0.00
BARIUM TOTAL	MEAN	.	.	95.15	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	300.00	.	.	.
	N	0.00	0.00	20.00	0.00	0.00	0.00
BERYLLIUM DISSOLVED	MEAN	.	0.55	0.54	.	.	.
	MIN	.	0.50	0.00	.	.	.
	MAX	.	0.70	1.00	.	.	.
	N	0.00	4.00	35.00	0.00	0.00	0.00
BORON DISSOLVED	MEAN	.	.	50.00	.	.	.
	MIN	.	.	30.00	.	.	.
	MAX	.	.	70.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00
CADMIUM DISSOLVED	MEAN	1.05	1.25	1.22	.	.	.
	MIN	1.00	1.00	0.00	.	.	.
	MAX	2.00	2.00	18.00	.	.	.
	N	21.00	4.00	80.00	0.00	0.00	0.00
CADMIUM SUSPENDED	MEAN	.	.	1.38	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	10.00	.	.	.
	N	0.00	0.00	13.00	0.00	0.00	0.00
CADMIUM TOTAL	MEAN	.	.	4.84	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	20.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
CHROMIUM DISSOLVED	MEAN	9.29	5.00	1.59	.	.	.
	MIN	0.00	5.00	0.00	.	.	.
	MAX	40.00	5.00	20.00	.	.	.
	N	21.00	4.00	80.00	0.00	0.00	0.00
CHROMIUM SUSPENDED	MEAN	.	.	4.75	.	.	.
	MIN	.	.	0.00	.	.	.

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
CHROMIUM SUSPENDED	MAX	.	.	20.00	.	.	.
	N	0.00	0.00	16.00	0.00	0.00	0.00
CHROMIUM TOTAL	MEAN	.	.	7.88	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	20.00	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
COBALT DISSOLVED	MEAN	.	3.00	1.96	.	.	.
	MIN	.	3.00	0.00	.	.	.
	MAX	.	3.00	3.00	.	.	.
	N	0.00	4.00	85.00	0.00	0.00	0.00
COBALT SUSPENDED	MEAN	.	.	5.27	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	50.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00
COBALT TOTAL	MEAN	.	.	20.16	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	100.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
COPPER DISSOLVED	MEAN	3.48	10.00	3.54	.	.	.
	MIN	1.00	10.00	0.00	.	.	.
	MAX	14.00	10.00	17.00	.	.	.
	N	21.00	4.00	80.00	0.00	0.00	0.00
COPPER SUSPENDED	MEAN	.	.	4.15	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	10.00	.	.	.
	N	0.00	0.00	20.00	0.00	0.00	0.00
COPPER TOTAL	MEAN	.	.	7.97	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	20.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
IRON SUSPENDED	MEAN	.	.	1383.33	.	.	.
	MIN	.	.	690.00	.	.	.
	MAX	.	.	2900.00	.	.	.
	N	0.00	0.00	18.00	0.00	0.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
IRON TOTAL	MEAN	.	.	1636.13	.	.	.
	MIN	.	.	790.00	.	.	.
	MAX	.	.	2900.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
IRON DISSOLVED	MEAN	135.33	233.00	199.94	.	.	.
	MIN	46.00	72.00	10.00	.	.	.
	MAX	480.00	390.00	920.00	.	.	.
	N	21.00	4.00	85.00	0.00	0.00	0.00
LEAD DISSOLVED	MEAN	4.90	10.00	5.63	.	.	.
	MIN	1.00	10.00	0.00	.	.	.
	MAX	25.00	10.00	160.00	.	.	.
	N	21.00	4.00	78.00	0.00	0.00	0.00
LEAD SUSPENDED	MEAN	.	.	22.32	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	150.00	.	.	.
	N	0.00	0.00	19.00	0.00	0.00	0.00
LEAD TOTAL	MEAN	.	.	62.97	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	310.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
MANGANESE SUSPENDED	MEAN	.	.	178.20	.	.	.
	MIN	.	.	30.00	.	.	.
	MAX	.	.	320.00	.	.	.
	N	0.00	0.00	20.00	0.00	0.00	0.00
MANGANESE TOTAL	MEAN	.	.	177.10	.	.	.
	MIN	.	.	10.00	.	.	.
	MAX	.	.	410.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
MANGANESE DISSOLVED	MEAN	28.90	30.75	39.86	.	.	.
	MIN	2.00	3.00	0.00	.	.	.
	MAX	150.00	95.00	890.00	.	.	.
	N	21.00	4.00	85.00	0.00	0.00	0.00
MOLYBDENUM DISSOLVED	MEAN	.	10.00	10.00	.	.	.
	MIN	.	10.00	10.00	.	.	.

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
MOLYBDENUM DISSOLVED	MAX	.	10.00	10.00	.	.	.
	N	0.00	4.00	40.00	0.00	0.00	0.00
NICKEL DISSOLVED	MEAN	.	10.00	2.81	.	.	.
	MIN	.	10.00	0.00	.	.	.
	MAX	.	10.00	17.00	.	.	.
	N	0.00	4.00	72.00	0.00	0.00	0.00
NICKEL SUSPENDED	MEAN	.	.	1.64	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	8.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00
NICKEL TOTAL	MEAN	24.00	.	4.33	.	.	.
	MIN	24.00	.	1.00	.	.	.
	MAX	24.00	.	11.00	.	.	.
	N	1.00	0.00	12.00	0.00	0.00	0.00
SILVER DISSOLVED	MEAN	0.86	1.25	0.75	.	.	.
	MIN	0.00	1.00	0.00	.	.	.
	MAX	1.00	2.00	4.00	.	.	.
	N	21.00	4.00	64.00	0.00	0.00	0.00
SILVER SUSPENDED	MEAN	.	.	0.75	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	10.00	.	.	.
	N	0.00	0.00	16.00	0.00	0.00	0.00
SILVER TOTAL	MEAN	.	.	1.17	0.03	.	.
	MIN	.	.	0.00	0.03	.	.
	MAX	.	.	20.00	0.03	.	.
	N	0.00	0.00	24.00	1.00	0.00	0.00
STRONTIUM DISSOLVED	MEAN	.	76.50	99.34	.	.	.
	MIN	.	64.00	47.00	.	.	.
	MAX	.	86.00	320.00	.	.	.
	N	0.00	4.00	61.00	0.00	0.00	0.00
VANADIUM DISSOLVED	MEAN	.	6.00	6.00	.	.	.
	MIN	.	6.00	6.00	.	.	.
	MAX	.	6.00	6.00	.	.	.
	N	0.00	4.00	40.00	0.00	0.00	0.00

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
ZINC DISSOLVED	MEAN	16.81	10.25	23.91	.	.	.
	MIN	3.00	6.00	0.00	.	.	.
	MAX	45.00	19.00	240.00	.	.	.
	N	21.00	4.00	79.00	0.00	0.00	0.00
ZINC SUSPENDED	MEAN	.	.	20.45	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	70.00	.	.	.
	N	0.00	0.00	20.00	0.00	0.00	0.00
ZINC TOTAL	MEAN	.	.	33.10	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	220.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
ALUMINUM DISSOLVED	MEAN	.	.	87.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	540.00	.	.	.
	N	0.00	0.00	60.00	0.00	0.00	0.00
LITHIUM DISSOLVED	MEAN	.	5.50	7.44	.	.	.
	MIN	.	4.00	0.00	.	.	.
	MAX	.	7.00	20.00	.	.	.
	N	0.00	4.00	61.00	0.00	0.00	0.00
SELENIUM DISSOLVED	MEAN	1.05	1.25	0.93	.	.	.
	MIN	0.00	1.00	0.00	.	.	.
	MAX	5.00	2.00	2.00	.	.	.
	N	21.00	4.00	72.00	0.00	0.00	0.00
SELENIUM SUSPENDED	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	16.00	0.00	0.00	0.00
SELENIUM TOTAL	MEAN	.	.	0.74	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	1.00	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
COLIFORM, TOTAL	MEAN	.	.	4820.27	.	.	.
	MIN	.	.	42.00	.	.	.

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
COLIFORM, TOTAL	MAX	.	.	34000.00	.	.	.
	N	0.00	0.00	45.00	0.00	0.00	0.00
COLIFORM, FECAL	MEAN	.	.	105.96	.	.	.
	MIN	.	.	14.00	.	.	.
	MAX	.	.	280.00	.	.	.
	N	0.00	0.00	24.00	0.00	0.00	0.00
COLIFORM FECAL 0.7	MEAN	.	.	121.77	.	.	.
	MIN	.	.	2.00	.	.	.
	MAX	.	.	4100.00	.	.	.
	N	0.00	0.00	122.00	0.00	0.00	0.00
FECAL STRPT KF AGAR	MEAN	.	.	194.10	.	.	.
	MIN	.	.	14.00	.	.	.
	MAX	.	.	2300.00	.	.	.
	N	0.00	0.00	122.00	0.00	0.00	0.00
FECAL STRPT MF M-ENT	MEAN	.	.	201.67	.	.	.
	MIN	.	.	14.00	.	.	.
	MAX	.	.	1400.00	.	.	.
	N	0.00	0.00	24.00	0.00	0.00	0.00
CHLORO-B-PERI-SUCORR	MEAN	.	.	0.15	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.71	.	.	.
	N	0.00	0.00	7.00	0.00	0.00	0.00
CHLORO-A-PERI-SUCORR	MEAN	.	.	3.12	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	10.20	.	.	.
	N	0.00	0.00	7.00	0.00	0.00	0.00
CHLORO-TOT-PHY-SUCOR	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	1.00	0.00	0.00	0.00
PHENOLS, TOTAL	MEAN	.	.	1.73	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	8.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
DETERGENTS (MBAS)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.03	.	.	.
	N	0.00	0.00	13.00	0.00	0.00	0.00
PERTHANE TOTAL	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	5.00	0.00	0.00	0.00
ALKALINITY,-DIS,IT,F	MEAN	.	.	15.95	.	.	.
	MIN	.	.	12.00	.	.	.
	MAX	.	.	21.00	.	.	.
	N	0.00	0.00	20.00	0.00	0.00	0.00
PCN TOTAL (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	11.00	0.00	0.00	0.00
PCN TOTAL BTM DRY	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	2.00	0.00	0.00	0.00
ALORIN TOTAL (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
ALDRIN BTM UG/KG	MEAN	.	.	0.04	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
LINDANE TOTAL(WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
LINDANE BTM UG/KG	MEAN	.	.	0.04	.	.	.
	MIN	.	.	0.00	.	.	.

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
LINDANE BTM UG/KG	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
CHLORDANE TOT(WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	37.00	0.00	0.00	0.00
CHLOROANE BTM UG/KG	MEAN	.	.	4.92	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	140.00	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
DDD TOTAL (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
ODD BTM	MEAN	.	.	0.27	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	8.00	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
DDE TOTAL (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
DOE BTM	MEAN	.	.	0.04	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
DDT TOTAL (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.06	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
OOT BTM	MEAN	.	.	0.08	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	1.40	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
DIELDRIN TOT (WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
DIELDRIN BTM	MEAN	.	.	0.43	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	12.00	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
TOXAPHENE BTM	MEAN	.	.	1.67	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	10.00	.	.	.
	N	0.00	0.00	24.00	0.00	0.00	0.00
HEPTACHLOR BTM UG/KG	MEAN	.	.	0.04	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
HEPT EPOX BTM UG/KG	MEAN	.	.	0.04	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	33.00	0.00	0.00	0.00
PCB BTM	MEAN	.	.	1.86	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	50.00	.	.	.
	N	0.00	0.00	28.00	0.00	0.00	0.00
MALATHION BTM UG/KG	MEAN	.	.	0.20	.	.	.
	MIN	.	.	0.20	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
PARATHION BTM UG/KG	MEAN	.	.	0.20	.	.	.
	MIN	.	.	0.20	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
MET PARTH TOT(WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
MET PARTH TOT(WATER)	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	35.00	0.00	0.00	0.00
MET PARTH BTM UG/KG	MEAN	.	.	0.20	.	.	.
	MIN	.	.	0.20	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
2,4-D BTM	MEAN	.	.	1.25	.	.	.
	MIN	.	.	0.60	.	.	.
	MAX	.	.	2.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
2,4,5-T TOTAL(WATER)	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.04	.	.	.
	N	0.00	0.00	48.00	0.00	0.00	0.00
2,4,5-T BTM	MEAN	.	.	0.17	.	.	.
	MIN	.	.	0.10	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
SILVEX TOTAL (WATER)	MEAN	.	.	0.02	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.77	.	.	.
	N	0.00	0.00	49.00	0.00	0.00	0.00
SILVEX BTM	MEAN	.	.	0.20	.	.	.
	MIN	.	.	0.20	.	.	.
	MAX	.	.	0.20	.	.	.
	N	0.00	0.00	4.00	0.00	0.00	0.00
PHYTO TYPE-I	MEAN	.	.	7247.37	.	.	.
	MIN	.	.	140.00	.	.	.
	MAX	.	.	47000.00	.	.	.
	N	0.00	0.00	57.00	0.00	0.00	0.00
RESIDUE DIS 180C	MEAN	.	.	103.32	.	94.00	.
	MIN	.	.	69.00	.	94.00	.
	MAX	.	.	139.00	.	94.00	.
	N	0.00	0.00	140.00	0.00	1.00	0.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
DISSOLVED SOLIDS SUM	MEAN	93.99	77.34	90.62	61.47	172.61	88.23
	MIN	76.49	58.69	35.00	17.00	21.88	32.30
	MAX	128.19	91.22	132.44	126.00	6590.00	481.00
	N	51.00	12.00	259.00	178.00	270.00	194.00
DISSOLVED SOLIDS	MEAN	1354.82	1888.77	1542.85	111.55	109.12	26.92
	MIN	394.71	522.96	9.23	5.19	0.80	0.97
	MAX	4481.64	3841.46	7200.90	1040.00	5120.00	1210.00
	N	51.00	12.00	258.00	178.00	271.00	190.00
RESIDUE DIS TON/ACFT	MEAN	0.13	0.11	0.13	0.08	0.24	0.12
	MIN	0.10	0.08	0.05	0.02	0.03	0.04
	MAX	0.17	0.12	0.19	0.17	8.96	0.65
	N	51.00	12.00	259.00	180.00	272.00	195.00
SED-SUSP-SIEVE-.062	MEAN	.	.	76.50	63.00	.	.
	MIN	.	.	12.00	48.00	.	.
	MAX	.	.	100.00	72.00	.	.
	N	0.00	0.00	145.00	3.00	0.00	0.00
PHOS ORTHO TOT AS P	MEAN	.	0.03	0.03	.	.	.
	MIN	.	0.01	0.01	.	.	.
	MAX	.	0.06	0.04	.	.	.
	N	0.00	6.00	12.00	0.00	0.00	0.00
NITROGEN, NH4, TOTAL	MEAN	0.10	0.06	0.07	.	0.03	.
	MIN	0.01	0.03	0.00	.	0.03	.
	MAX	1.13	0.23	0.59	.	0.03	.
	N	47.00	11.00	139.00	0.00	1.00	0.00
NITR. NH4 AS NH4 DIS	MEAN	.	.	0.07	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.36	.	.	.
	N	0.00	0.00	84.00	0.00	0.00	0.00
NITR. NO3 AS NO3 DIS	MEAN	.	.	0.47	0.65	1.38	0.31
	MIN	.	.	0.00	0.00	0.40	0.00
	MAX	.	.	2.50	2.20	7.70	1.30
	N	0.00	0.00	50.00	66.00	72.00	19.00
PHOSPHORUS TOT PO4	MEAN	0.14	.	0.18	.	.	.
	MIN	0.09	.	0.03	.	.	.

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
PHOSPHORUS TOT PO4	MAX	0.31	.	0.61	.	.	.
	N	20.00	0.00	44.00	0.00	0.00	0.00
NITROGEN, TOTAL -NO3	MEAN	3.16	3.85	3.41	.	3.41	.
	MIN	2.21	2.26	0.57	.	3.41	.
	MAX	3.98	5.45	7.88	.	3.41	.
	N	5.00	2.00	89.00	0.00	1.00	0.00
MERCURY DISSOLVED	MEAN	0.20	0.13	0.26	.	.	.
	MIN	0.00	0.10	0.00	.	.	.
	MAX	1.70	0.20	2.80	.	.	.
	N	21.00	4.00	76.00	0.00	0.00	0.00
MERCURY SUSPENDED	MEAN	.	.	0.14	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.70	.	.	.
	N	0.00	0.00	18.00	0.00	0.00	0.00
MERCURY, TOT.REC.	MEAN	.	.	0.36	.	.	.
	MIN	.	.	0.10	.	.	.
	MAX	.	.	2.20	.	.	.
	N	0.00	0.00	31.00	0.00	0.00	0.00
SAMPLE PURPOSE	MEAN	.	.	20.00	.	.	.
	MIN	.	.	20.00	.	.	.
	MAX	.	.	20.00	.	.	.
	N	0.00	0.00	14.00	0.00	0.00	0.00
CONCENTRATI-ON,S.SED.	MEAN	.	.	46.05	59.33	.	.
	MIN	.	.	11.00	45.00	.	.
	MAX	.	.	190.00	73.00	.	.
	N	0.00	0.00	145.00	3.00	0.00	0.00
DISCHARGE,S-USP.SED.	MEAN	.	.	733.72	.	.	.
	MIN	.	.	10.15	.	.	.
	MAX	.	.	4950.18	.	.	.
	N	0.00	0.00	145.00	0.00	0.00	0.00
POTSSSIUM 40 DISS.	MEAN	1.95	.	2.08	0.70	0.90	0.93
	MIN	1.90	.	1.60	0.70	0.70	0.80
	MAX	2.00	.	2.50	0.70	1.10	1.20
	N	2.00	0.00	5.00	1.00	2.00	4.00

(CONTINUED)

		STATION					
		08040500-Steinhagen Lake	08040600-Neches @ Town Bluff	08041000-Neches @ Evadale	08041500-Village Creek	08041700-Pine Island Bayou	08066300-Menard Creek
SPECIFIC CONDUCTANCE	MEAN	162.35	130.00	148.49	87.14	233.58	101.99
	MIN	122.00	96.00	75.00	40.00	52.00	52.80
	MAX	212.00	148.00	206.00	127.00	1010.00	277.00
	N	51.00	12.00	79.00	35.00	50.00	90.00
ALKALINITY	MEAN	.	.	17.95	3.00	.	.
	MIN	.	.	10.00	3.00	.	.
	MAX	.	.	28.00	3.00	.	.
	N	0.00	0.00	76.00	1.00	0.00	0.00
TOTAL COUNT	MEAN	.	.	7130.00	.	.	.
	MIN	.	.	140.00	.	.	.
	MAX	.	.	47000.00	.	.	.
	N	0.00	0.00	58.00	0.00	0.00	0.00
HARDNESS, NONCARB	MEAN	.	.	10.87	.	.	.
	MIN	.	.	7.00	.	.	.
	MAX	.	.	23.00	.	.	.
	N	0.00	0.00	15.00	0.00	0.00	0.00
BICARBONATE	MEAN	.	.	19.33	.	.	.
	MIN	.	.	11.00	.	.	.
	MAX	.	.	29.00	.	.	.
	N	0.00	0.00	6.00	0.00	0.00	0.00
CARBONATE	MEAN	.	.	0.00	.	.	.
	MIN	.	.	0.00	.	.	.
	MAX	.	.	0.00	.	.	.
	N	0.00	0.00	6.00	0.00	0.00	0.00
SULFATE, D. UNCORCT	MEAN	1.00	8.00	8.00	.	.	4.75
	MIN	1.00	1.00	1.00	.	.	1.00
	MAX	1.00	15.00	16.00	.	.	13.00
	N	1.00	2.00	4.00	0.00	0.00	4.00

Appendix B

Summary of Data for

Big Thicket National Preserve Stations

SUMMARY OF DATA FOR BTNP STATIONS

	WATER TEMPERATURE				PH, FIELD				OXYGEN DISSOLVED				TURBIDITY (NTU)				SPECIFIC CONDUCTANCE			
	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
SITE																				
Beech Creek at Best Rd.	17.88	6.00	27.00	74	6.13	3.43	9.45	73	5.95	0.30	15.10	69	16.16	5.20	70.30	73	65.73	5.00	317.00	73
Beech Creek at South Boundary	18.22	6.00	28.00	91	6.32	4.79	8.14	90	6.85	1.00	12.90	87	10.11	1.70	30.90	89	46.06	2.00	68.00	90
Mill Creek	18.45	4.00	29.00	84	6.68	5.15	7.23	83	7.92	3.80	12.00	76	18.44	4.70	64.30	83	75.86	8.00	105.00	84
Big Sandy Creek at FM1276 North	19.02	4.00	28.00	93	6.80	5.60	8.55	92	7.93	4.00	11.70	87	19.85	1.90	64.60	91	90.44	4.00	531.00	93
Big Sandy Creek at Sunflower Rd.	19.13	3.50	28.00	93	6.81	5.77	8.37	92	7.81	4.53	12.40	86	20.94	4.90	109.10	90	84.51	3.00	353.00	93
Big Sandy Creek at FM1276 South	19.23	4.00	28.00	95	6.77	5.89	8.31	94	7.71	2.59	12.20	88	18.75	4.60	76.60	92	64.89	2.00	213.00	93
Big Sandy Creek at Woodlands Tr.	19.08	9.00	27.00	20	6.69	6.01	7.28	20	8.31	5.00	10.65	18	15.71	5.65	40.70	20	81.90	40.00	104.00	20
Black Creek above Sandlot Lake	19.06	4.00	32.00	56	6.18	4.74	7.32	55	5.39	0.60	11.90	48	18.75	2.00	76.50	55	75.18	25.00	179.00	56
Black Creek at Timber Slough Rd.	18.13	5.20	30.00	33	6.22	5.07	6.97	32	5.50	0.70	11.60	31	19.10	4.10	39.00	32	87.03	47.00	172.00	33
Neches River at Weiss Bluff	19.95	9.00	31.00	23	6.95	6.26	7.50	23	7.52	3.40	10.90	22	22.41	5.20	78.10	23	127.91	5.00	203.00	23
Neches River at Lakeview	20.58	9.50	30.00	24	6.90	6.32	7.41	25	7.29	3.80	10.22	24	22.27	5.00	74.60	24	121.42	5.00	146.00	24
Neches River at Pine Island Bayou	20.05	10.00	30.00	22	6.76	5.90	7.46	22	7.22	3.50	11.00	21	23.68	4.80	73.40	22	118.68	10.00	145.00	22
Little Pine Island Bayou at FM770	19.86	5.40	31.33	94	6.27	5.18	8.62	93	4.26	0.30	12.29	86	19.33	2.50	131.80	90	560.65	14.00	16241.00	94

SUMMARY OF DATA FOR BTNP STATIONS

SITE	WATER TEMPERATURE				PH, FIELD				OXYGEN DISSOLVED				TURBIDITY (NTU)				SPECIFIC CONDUCTANCE			
	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
Little Pine Island Bayou at Teel Rd.	19.93	4.00	30.00	92	6.39	5.40	7.85	91	4.81	1.10	11.50	84	18.14	2.50	64.20	89	198.68	11.00	1062.00	92
Little Pine Island Bayou at SH326	19.45	5.00	29.00	94	6.52	5.56	8.14	92	5.51	1.40	11.60	86	21.94	2.80	116.20	91	166.12	6.00	611.00	94
Little Pine Island Bayou at Bevil Oaks	20.31	7.00	30.00	92	6.82	5.98	8.33	92	5.86	2.68	12.30	85	49.52	8.90	129.60	88	193.08	7.00	1022.00	93
Little Pine Island Bayou at US69/96	21.04	5.90	30.41	92	6.72	5.60	8.37	91	6.08	2.00	11.30	84	40.02	5.34	114.20	88	135.46	6.00	332.00	92
Menard Creek at FM943	19.32	3.00	29.00	93	6.65	5.87	8.13	92	7.20	2.60	12.40	87	16.58	3.00	55.10	89	55.51	6.00	78.00	93
Menard Creek at SH146	20.11	5.00	30.00	93	6.67	5.85	8.33	92	7.92	4.30	12.20	87	15.09	3.90	45.30	90	80.51	10.00	125.00	93
Turkey Creek at FM 1943	19.17	5.00	28.00	93	6.78	5.67	8.32	92	7.84	4.00	13.26	88	22.74	5.20	210.00	91	57.45	5.00	102.00	91
Turkey Creek at Hickbaugh Rd.	19.20	5.00	29.00	93	6.73	5.33	8.36	92	7.70	3.92	13.20	89	19.74	3.08	69.50	91	55.43	3.00	78.00	93
Turkey Creek at County Line Rd.	19.34	5.00	30.00	95	6.66	5.33	8.20	94	7.36	0.20	13.20	90	20.39	5.60	58.10	92	54.17	3.00	76.00	95
Neches River at FM1013	20.81	9.00	30.00	22	6.88	6.07	7.47	22	7.76	4.00	11.40	22	25.22	8.10	84.10	22	121.52	13.00	150.00	21
Neches River at Timber Slough Rd.	20.50	9.50	30.00	7	6.76	6.25	7.10	7	8.70	4.00	12.29	7	19.17	8.80	33.70	7	145.86	122.00	162.00	7
Village Creek at McNeely Bridge	19.73	6.00	30.00	90	6.60	5.15	8.19	89	7.64	4.00	13.20	84	17.51	4.80	39.60	88	60.77	3.00	112.00	90

SUMMARY OF DATA FOR BTNP STATIONS

	ALKALINITY				CHLORIDE				SULFATE				COLOR			
SITE	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
Beech Creek at Best Rd.	10.00	1.00	30.00	27	12.86	5.00	130.00	28	17.36	5.00	39.00	14	147.32	25.00	300.00	28
Beech Creek at South Boundary	7.44	1.00	17.00	34	7.55	4.00	12.00	34	17.35	6.00	29.00	17	100.53	20.00	175.00	34
Mill Creek	19.53	12.00	38.00	32	11.16	2.00	19.00	32	11.63	6.00	20.00	16	62.09	30.00	110.00	32
Big Sandy Creek at FM1276 North	20.56	5.00	30.00	34	16.12	4.00	109.00	34	10.83	5.00	21.00	18	53.68	20.00	110.00	34
Big Sandy Creek at Sunflower Rd.	18.41	4.00	28.00	34	14.43	4.00	80.00	34	11.18	6.00	29.00	17	52.26	30.00	120.00	34
Big Sandy Creek at FM1276 South	14.38	5.00	20.00	34	11.37	6.00	44.00	34	10.18	5.00	20.00	17	59.74	30.00	116.00	34
Big Sandy Creek at Woodlands Tr.	21.71	8.00	32.00	17	11.59	8.00	16.00	17	10.67	6.00	23.00	9	48.71	25.00	100.00	17
Black Creek above Sandlot Lake	9.44	4.00	27.00	18	13.00	8.00	20.00	18	21.67	6.00	75.00	12	118.71	30.00	250.00	17
Black Creek at Timber Slough Rd.	10.64	3.00	30.00	11	11.09	7.00	14.00	11	24.80	10.00	70.00	5	129.50	25.00	250.00	10
Neches River at Weiss Bluff	16.76	6.00	22.00	21	17.17	8.00	25.00	21	21.05	13.00	32.00	21	53.24	10.00	125.00	21
Neches River at Lakeview	16.05	7.00	22.00	21	17.17	8.00	24.00	21	21.33	10.00	36.00	21	55.48	15.00	110.00	21
Neches River at Pine Island Bayou	17.00	7.00	36.00	21	16.79	8.00	23.00	21	20.95	13.00	32.00	21	55.95	15.00	110.00	21
Little Pine Island Bayou at FM770	10.23	2.00	25.00	30	82.20	4.00	1400.00	30	22.70	10.00	44.00	20	163.72	30.00	425.00	29

SUMMARY OF DATA FOR BTNP STATIONS

	ALKALINITY				CHLORIDE				SULFATE				COLOR			
	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
SITE																
Little Pine Island Bayou at Teel Rd.	12.72	2.00	28.00	29	53.41	5.00	178.00	29	26.00	12.00	56.00	19	157.38	9.00	425.00	29
Little Pine Island Bayou at SH326	18.73	4.00	45.00	30	37.72	6.00	131.00	30	21.05	5.00	45.00	21	134.83	9.00	290.00	30
Little Pine Island Bayou at Bevil Oaks	34.47	9.00	67.00	30	41.10	3.00	110.00	30	20.09	6.00	50.00	22	109.50	14.00	260.00	30
Little Pine Island Bayou at US69/96	26.66	9.00	56.00	29	26.00	4.00	57.00	29	22.65	12.00	50.00	20	94.00	11.00	185.00	29
Menard Creek at FM943	9.00	1.00	14.00	31	9.68	5.00	17.00	31	12.67	5.00	21.00	18	76.06	32.00	150.00	31
Menard Creek at SH146	10.94	3.00	33.00	31	18.68	7.00	28.00	31	12.00	6.00	25.00	15	65.48	20.00	150.00	31
Turkey Creek at FM 1943	12.32	4.00	18.00	34	8.16	4.00	14.00	34	10.73	5.00	23.00	15	54.00	28.00	100.00	34
Turkey Creek at Hickbaugh Rd.	12.62	4.00	19.00	34	8.04	4.00	14.00	34	10.13	5.00	22.00	15	57.47	25.00	160.00	34
Turkey Creek at County Line Rd.	12.21	4.00	18.00	34	7.94	3.00	13.00	34	10.41	5.00	23.00	17	57.06	25.00	120.00	34
Neches River at FM1013	17.30	9.00	22.00	20	17.82	9.00	25.00	20	21.11	13.00	29.00	18	52.80	15.00	150.00	20
Neches River at Timber Slough Rd.	18.14	14.00	20.00	7	24.00	16.00	41.00	7	22.00	15.00	30.00	7	35.71	20.00	80.00	7
Village Creek at McNeely Bridge	11.26	4.00	17.00	34	9.72	4.00	18.00	34	12.41	6.00	25.00	17	74.50	35.00	180.00	34

SUMMARY OF DATA FOR BTNP STATIONS

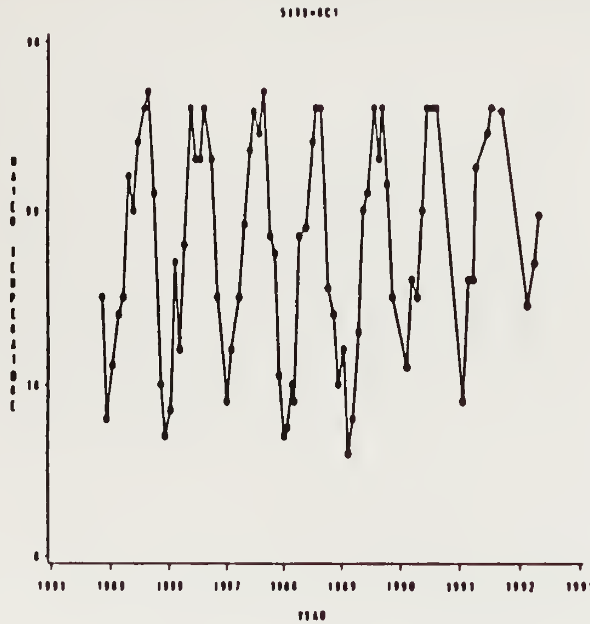
	TOTAL SUSP. SOLIDS				TOTAL DISS. SOLIDS				FECAL COLIF/100 ml				FECAL STREP/100 ml			
SITE	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
Beech Creek at Best Rd.	14.64	3.00	43.00	28	89.04	42.00	132.00	28	586.46	20.00	8100.00	24	1204.00	10.00	18200.00	25
Beech Creek at South Boundary	8.98	1.00	36.00	33	75.16	34.00	107.00	34	387.50	10.00	4500.00	30	520.17	40.00	3600.00	30
Mill Creek	10.92	2.00	30.00	32	84.67	37.00	114.00	32	231.25	100.00	470.00	32	480.62	40.00	2500.00	32
Big Sandy Creek at FM1276 North	13.24	2.00	58.00	34	95.79	32.00	235.00	34	337.83	20.00	4400.00	30	582.50	30.00	6800.00	32
Big Sandy Creek at Sunflower Rd.	13.37	2.00	60.00	34	92.81	42.00	210.00	34	260.31	20.00	4300.00	32	410.62	40.00	6200.00	32
Big Sandy Creek at FM1276 South	13.07	2.00	53.00	34	80.87	38.00	143.00	34	229.85	20.00	3300.00	33	341.91	10.00	6100.00	34
Big Sandy Creek at Woodlands Tr.	12.82	5.00	24.00	17	89.88	48.00	114.00	17	154.06	50.00	300.00	16	236.47	20.00	750.00	17
Black Creek above Sandlot Lake	8.61	2.00	16.00	18	103.06	51.00	137.00	18	95.59	5.00	270.00	17	183.61	20.00	1520.00	18
Black Creek at Timber Slough Rd.	11.09	4.00	18.00	11	105.91	70.00	139.00	11	146.00	50.00	400.00	10	904.09	40.00	5540.00	11
Neches River at Weiss Bluff	34.12	13.00	108.50	21	125.74	76.00	167.00	21	103.42	20.00	400.00	19	226.67	10.00	710.00	21
Neches River at Lakeview	28.90	20.00	42.00	21	121.00	84.00	161.00	21	91.43	20.00	280.00	21	171.67	20.00	520.00	21
Neches River at Pine Island Bayou	28.93	18.00	78.50	21	120.36	80.00	177.00	21	92.86	10.00	360.00	21	253.81	10.00	800.00	21
Little Pine Island Bayou at FM770	22.55	2.00	190.00	30	254.91	83.00	2725.00	29	227.86	20.00	1100.00	28	439.63	15.00	4050.00	27

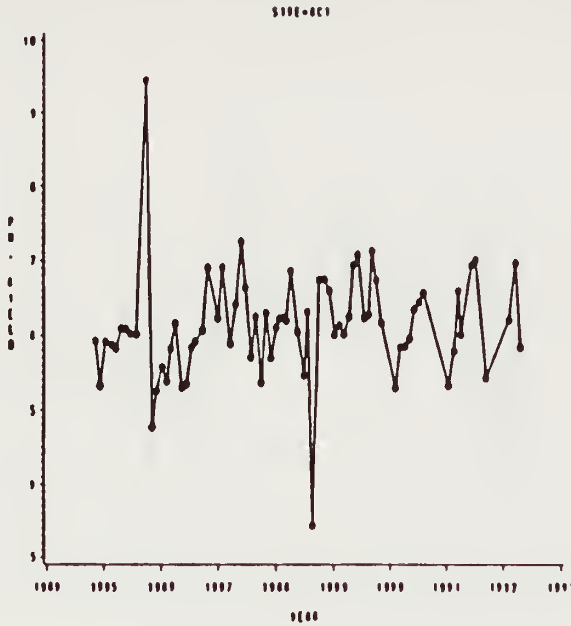
SUMMARY OF DATA FOR BTNP STATIONS

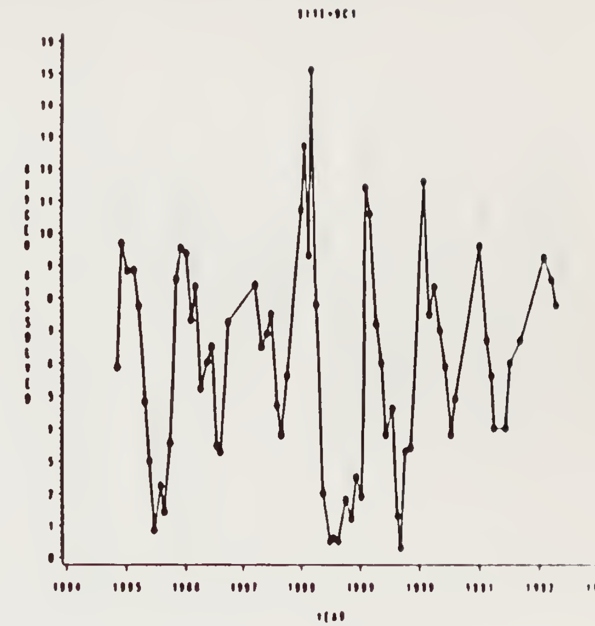
	TOTAL SUSP. SOLIDS				TOTAL DISS. SOLIDS				FECAL COLIF/100 ml				FECAL STREP/100 ml			
SITE	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N	MEAN	MIN	MAX	N
Little Pine Island Bayou at Teel Rd.	23.93	5.00	196.00	29	193.86	85.00	421.00	29	170.71	10.00	420.00	28	277.24	15.00	2030.00	29
Little Pine Island Bayou at SH326	21.32	2.00	194.00	30	169.82	100.00	333.00	30	395.00	20.00	3500.00	30	601.03	20.00	3300.00	29
Little Pine Island Bayou at Bevil Oaks	36.13	10.00	199.00	30	204.13	98.00	301.00	30	229.46	20.00	940.00	28	420.33	20.00	2700.00	30
Little Pine Island Bayou at US69/96	29.67	9.00	183.00	29	170.22	106.00	261.00	29	266.07	20.00	2500.00	28	200.19	20.00	1060.00	27
Menard Creek at FM943	8.50	1.00	52.00	30	74.03	34.00	109.00	31	302.06	10.00	5700.00	31	346.83	20.00	5200.00	30
Menard Creek at SH146	19.27	2.00	232.00	30	89.42	53.00	120.00	31	285.03	30.00	4050.00	30	622.86	10.00	8700.00	28
Turkey Creek at FM 1943	18.09	3.00	92.00	34	71.03	36.00	110.00	33	322.50	40.00	3700.00	30	1527.19	40.00	23300.00	32
Turkey Creek at Hickbaugh Rd.	17.62	4.00	49.00	34	72.91	38.00	106.00	34	338.28	30.00	4100.00	32	407.19	10.00	4600.00	32
Turkey Creek at County Line Rd.	18.90	3.00	62.00	34	71.96	38.00	96.00	34	210.97	10.00	700.00	31	366.45	10.00	2800.00	31
Neches River at FM1013	27.45	15.00	73.00	20	126.95	86.00	179.00	20	73.85	10.00	300.00	13	130.83	10.00	420.00	18
Neches River at Timber Slough Rd.	22.29	16.00	28.00	7	126.57	109.00	167.00	7	39.00	15.00	110.00	5	33.57	10.00	60.00	7
Village Creek at McNeely Bridge	12.74	3.00	30.00	34	80.50	33.00	111.00	34	198.23	10.00	1140.00	31	301.13	20.00	1480.00	31

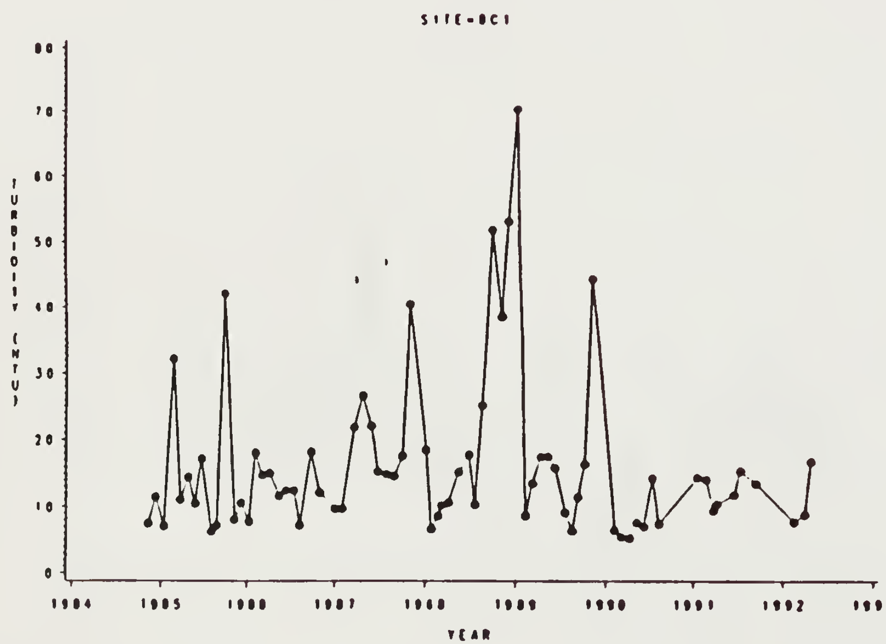
Appendix C

Graphs of all BTNP Water Quality Parameters





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10
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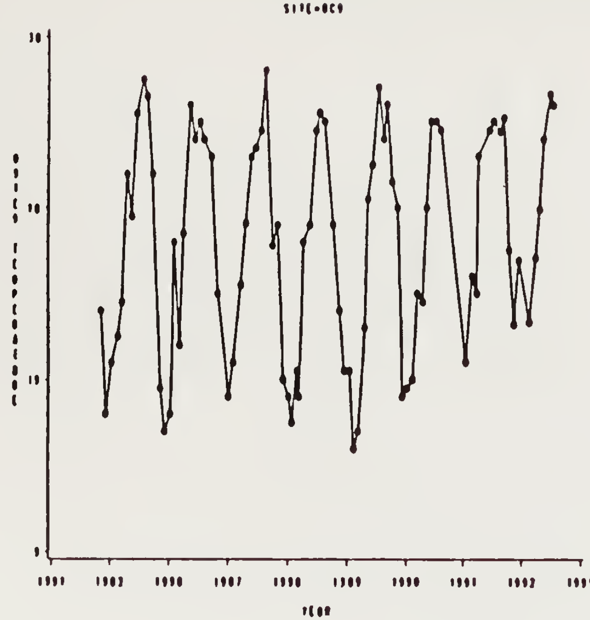
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
YEAR


SITE-BC1
SPECIFIC CONDUCTANCE
0
100
200
300
400
YEAR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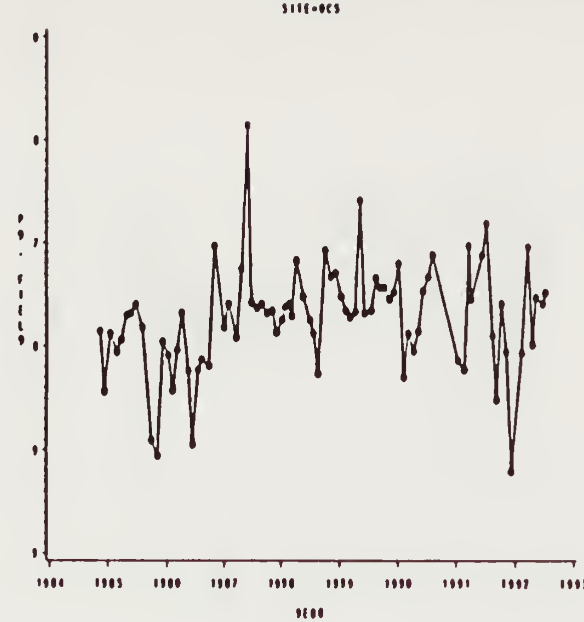
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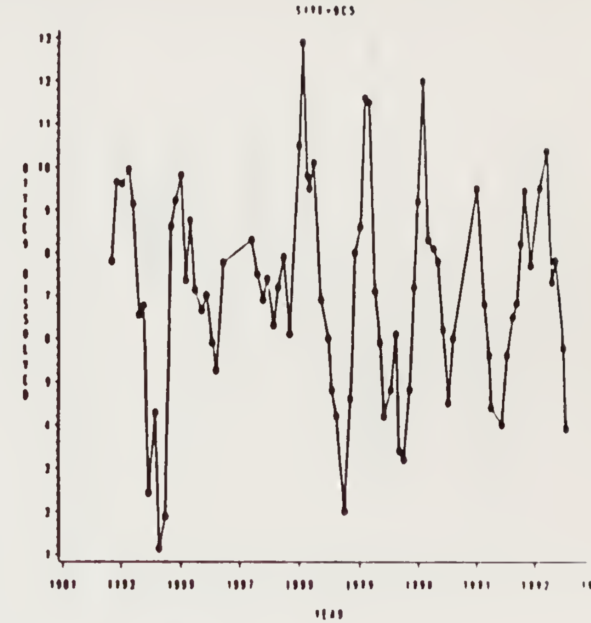
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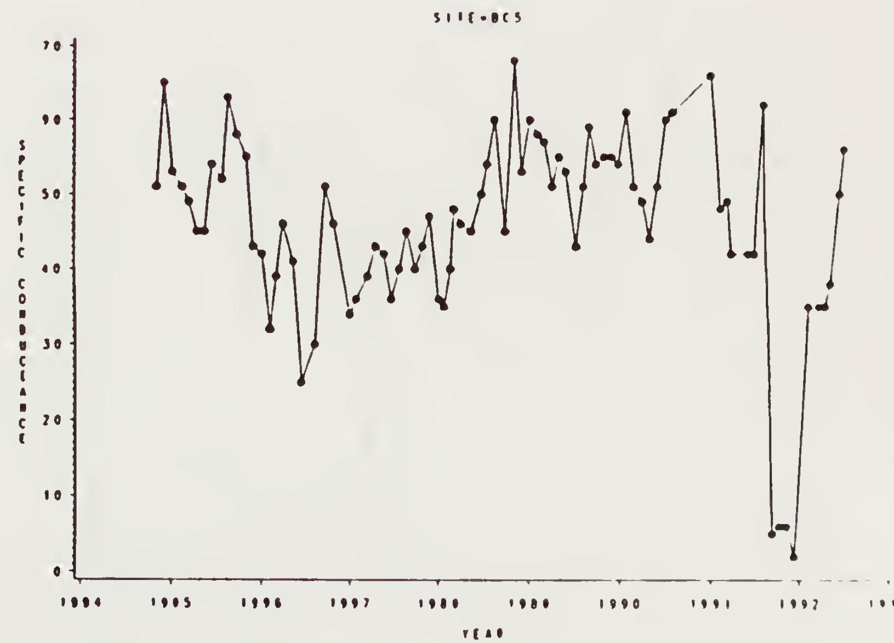
SITE=BCS
TURBIDITY (NTU)
YEAR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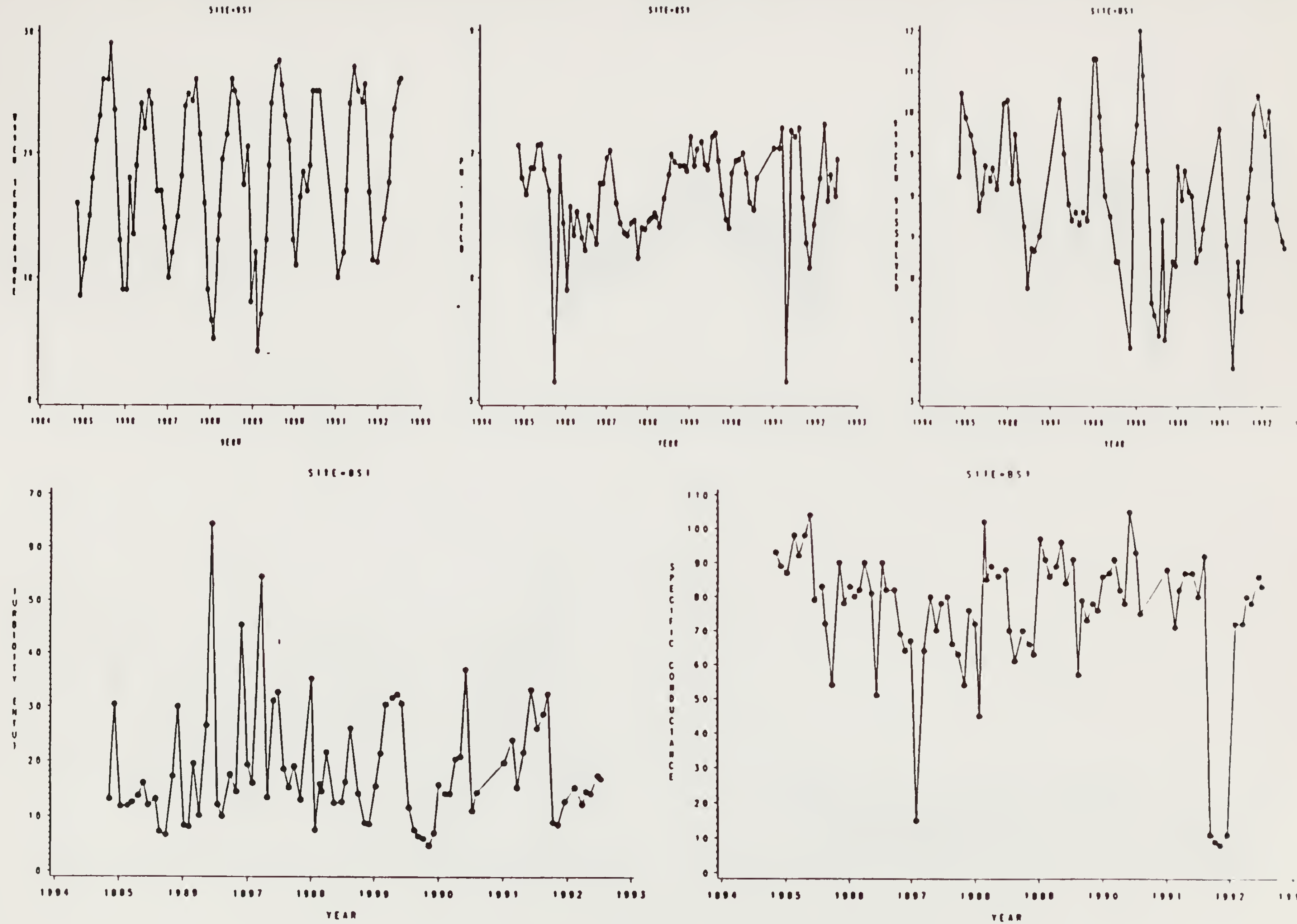
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YEAR
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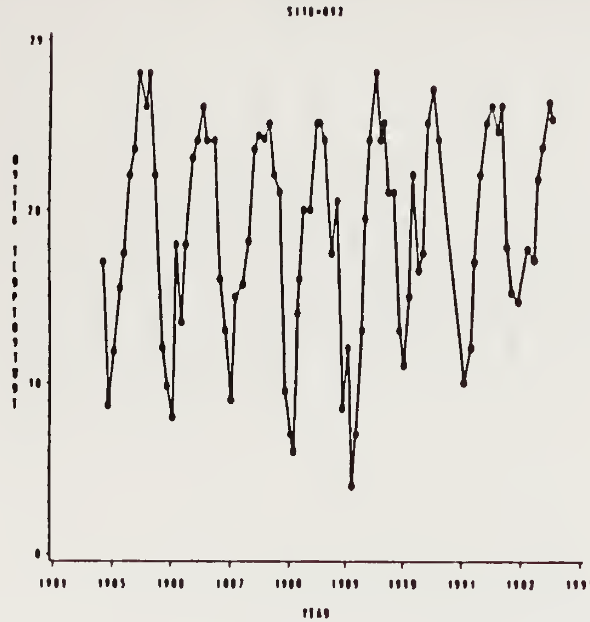
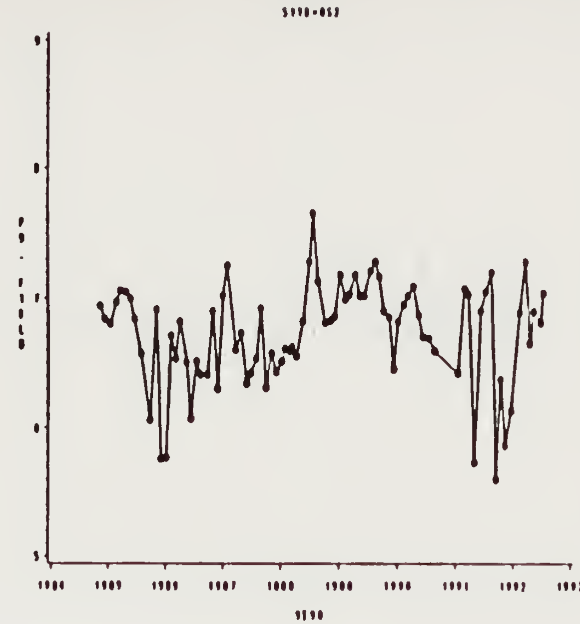
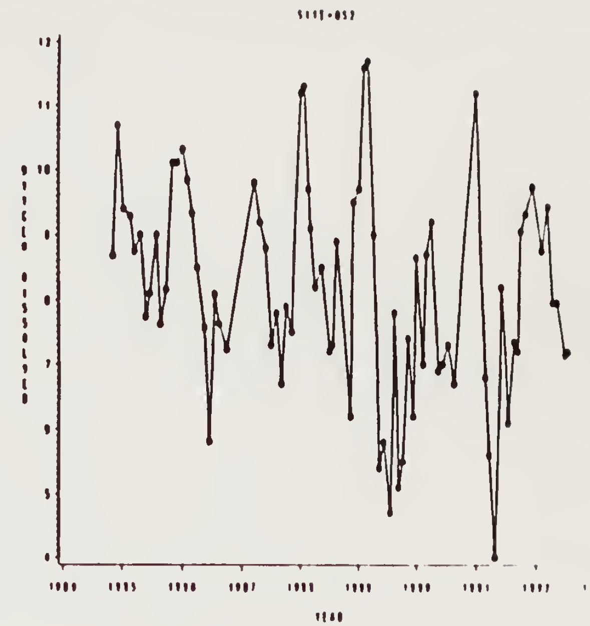
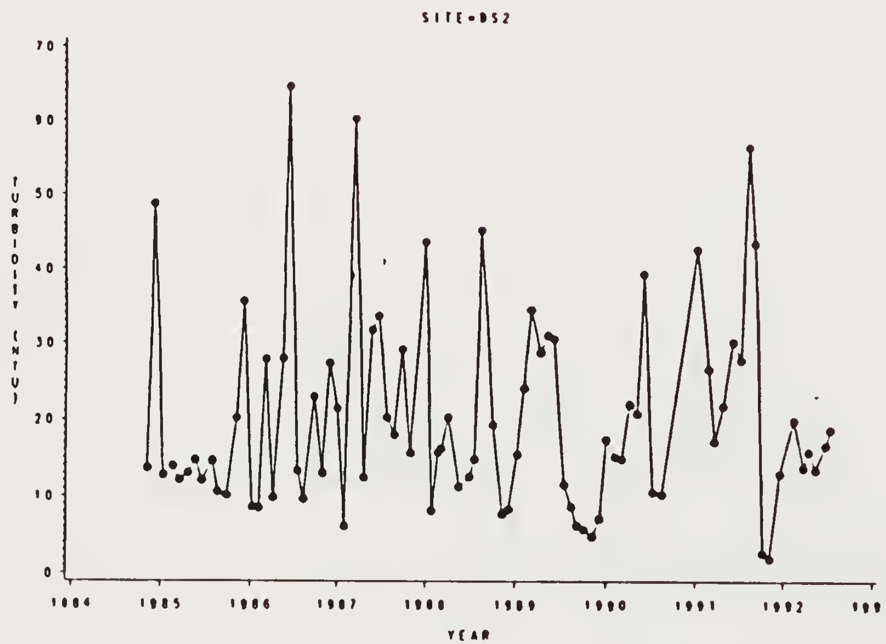
YEAR





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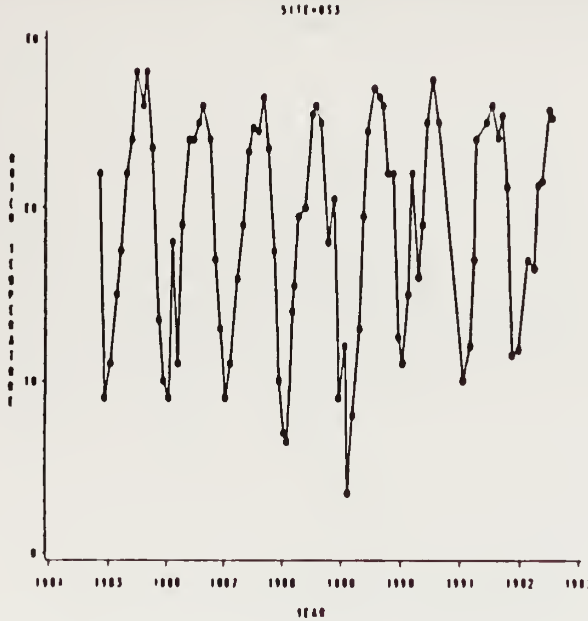
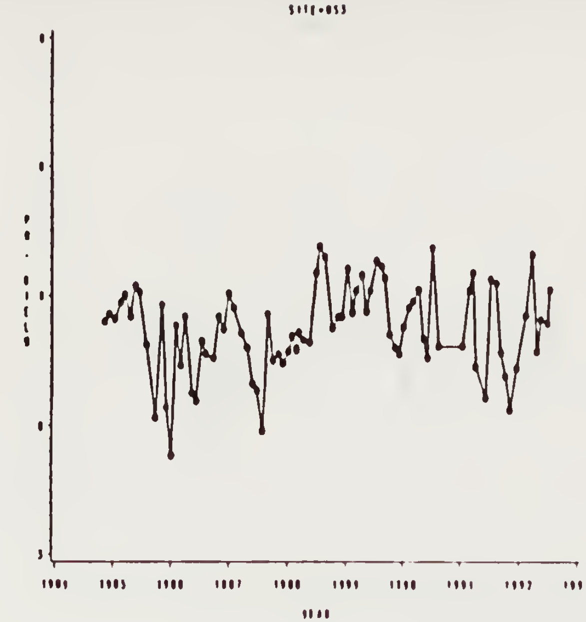
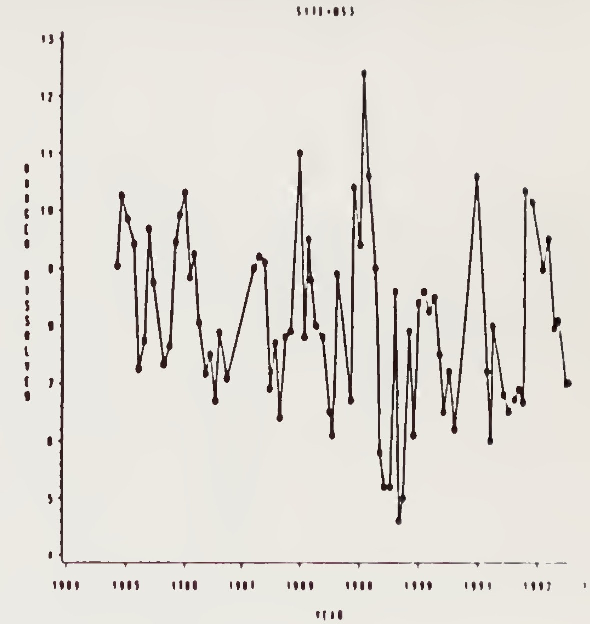
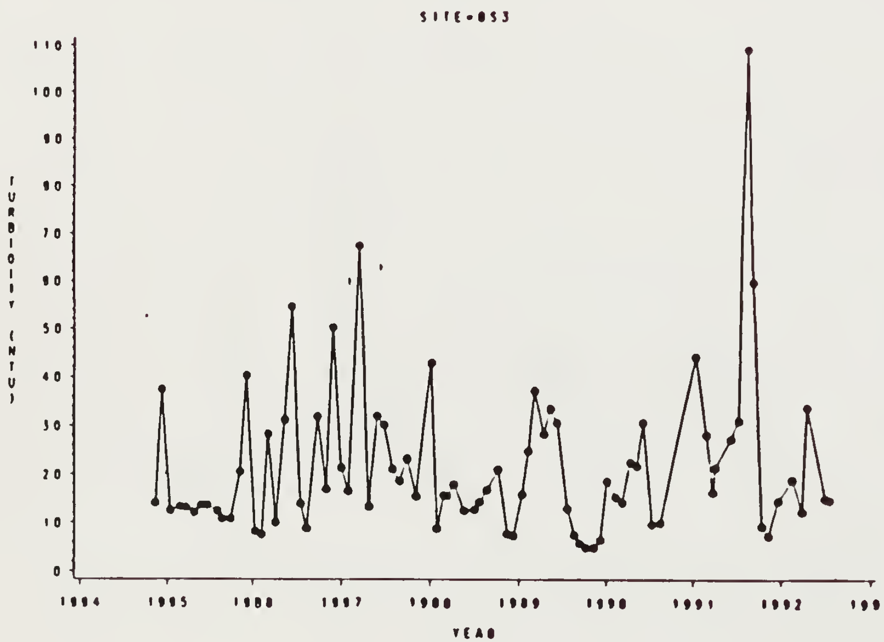
YEAR


SITE=BS2
SPECIFIC CONDUCTANCE
YEAR





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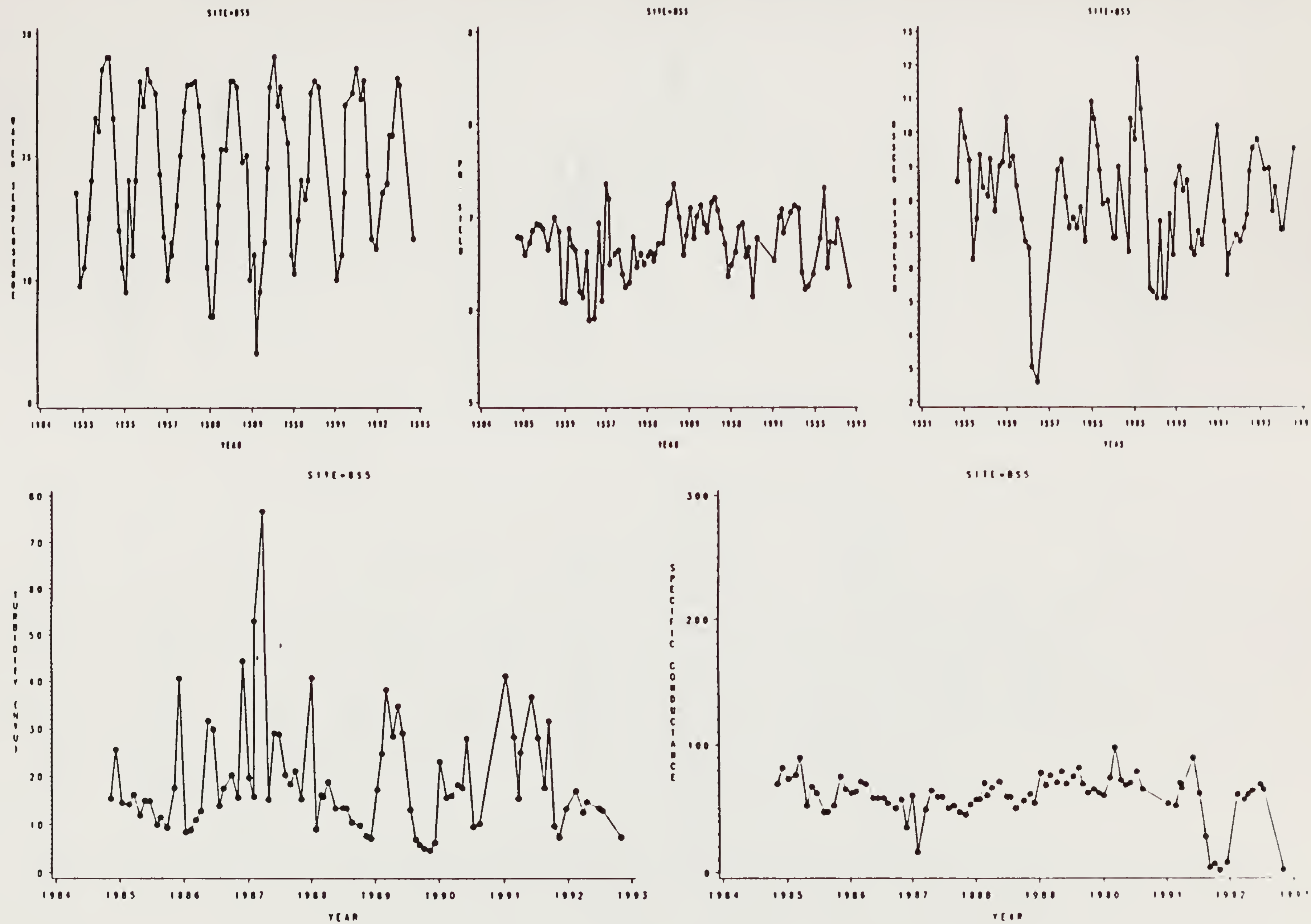
TURBIDITY (NTU)
YEAR


SITE=BS3
SPECIFIC CONDUCTANCE
YEAR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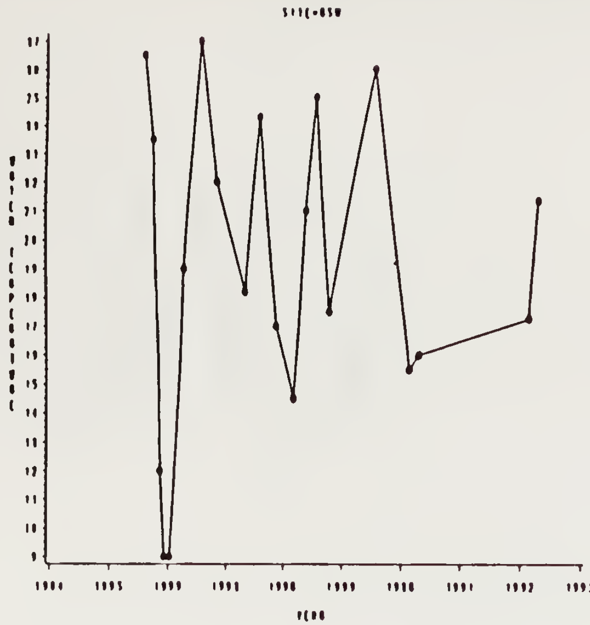
TURBIDITY (NTU)
SPECIFIC CONDUCTANCE
YEAR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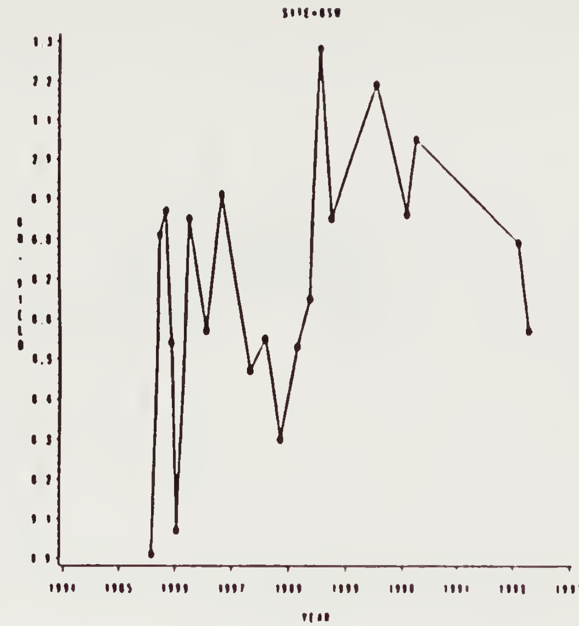
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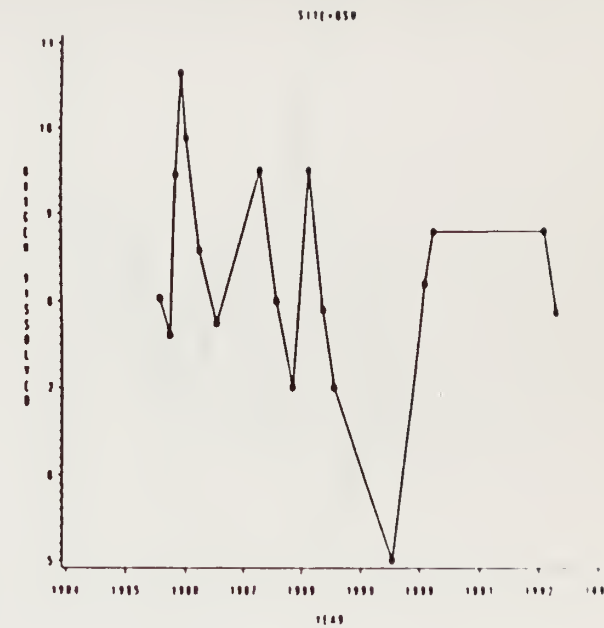
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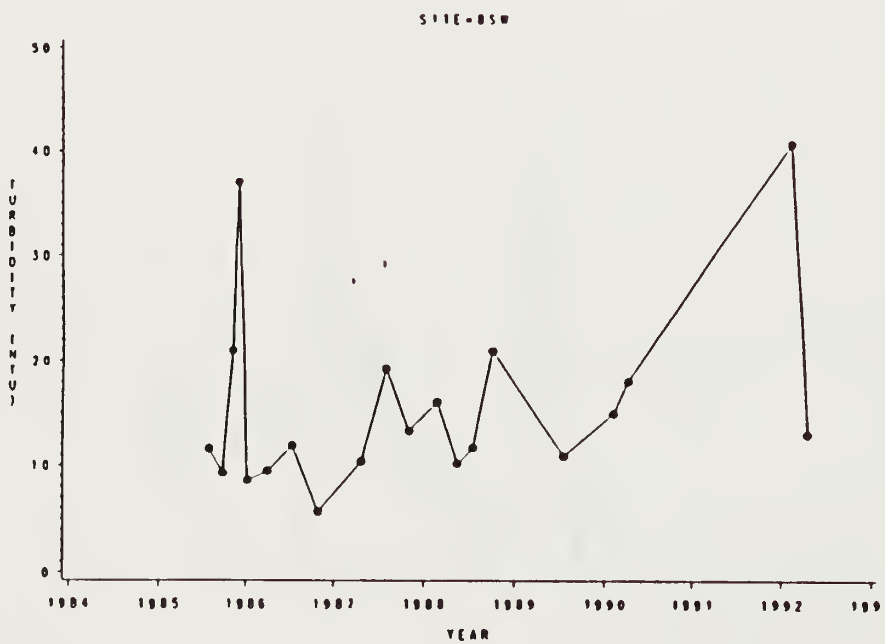
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1985
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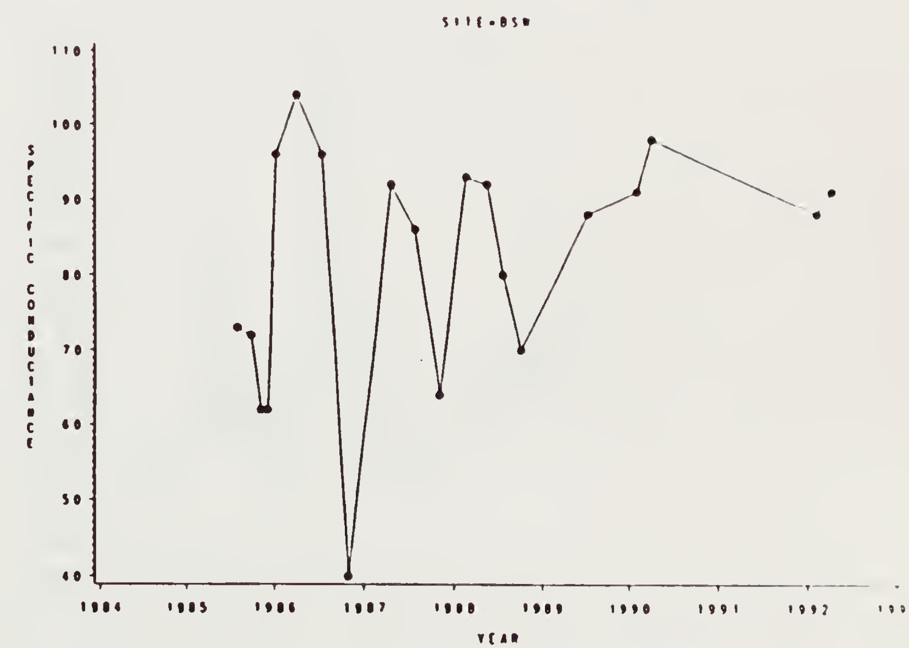
1988
1989
1990
1991
1992
1993
YEAR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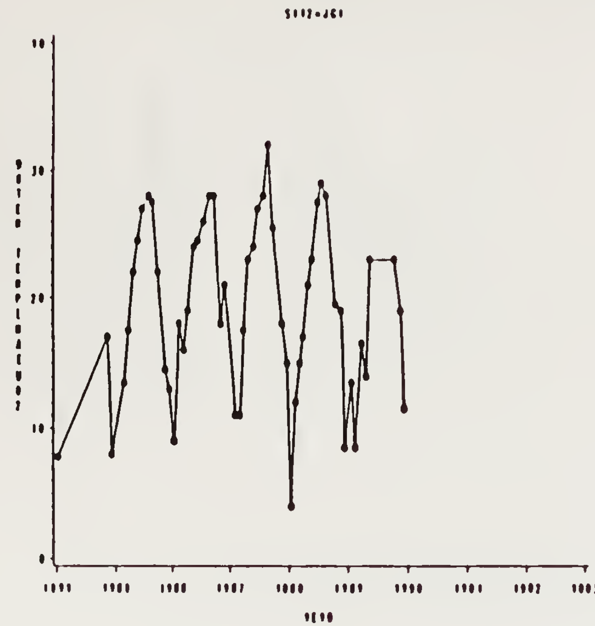
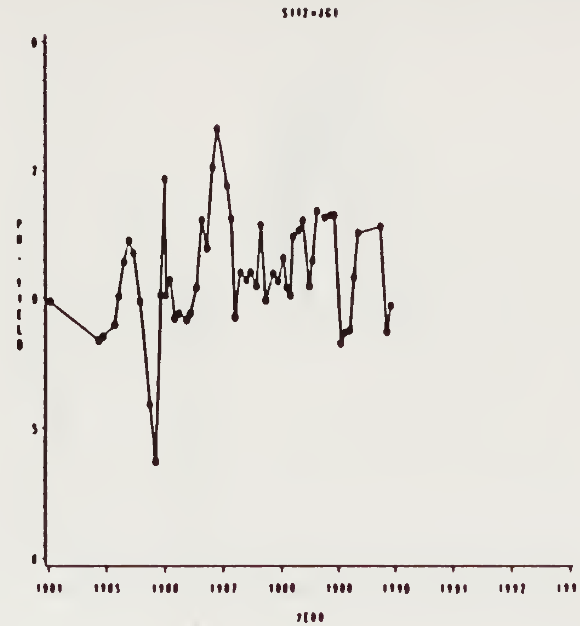
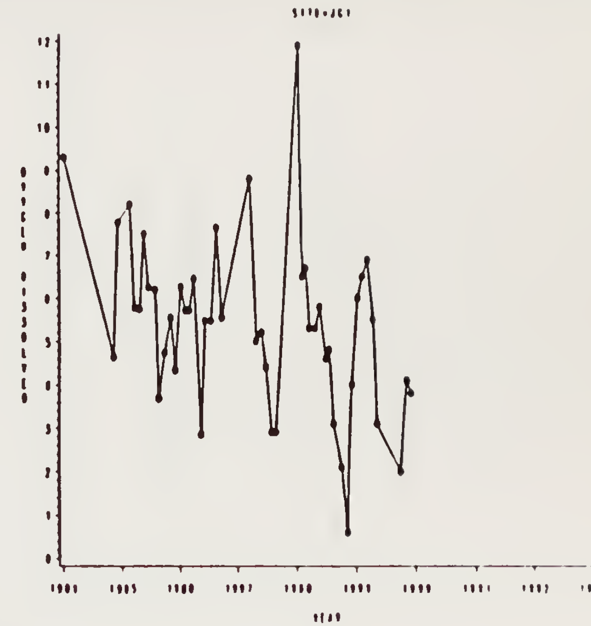
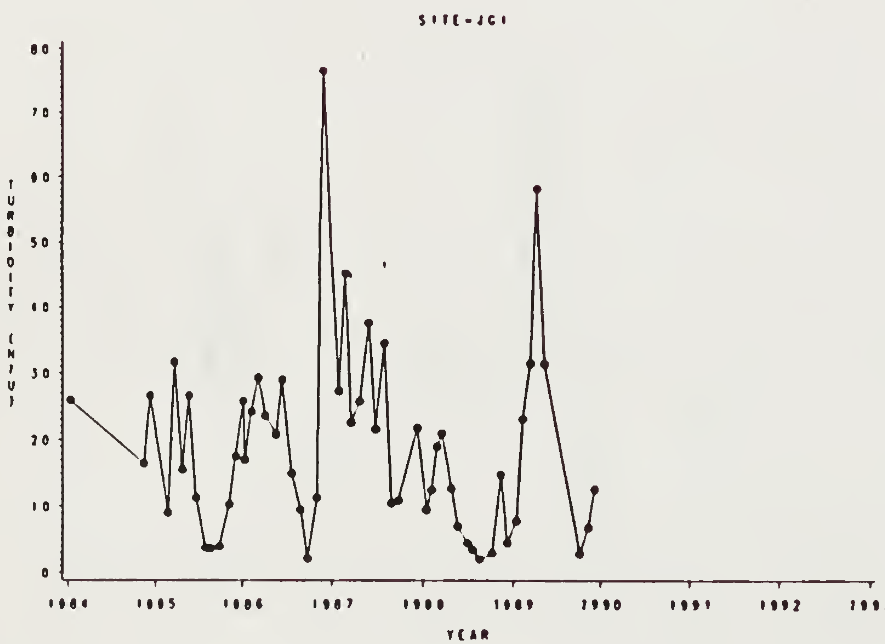
YEAR





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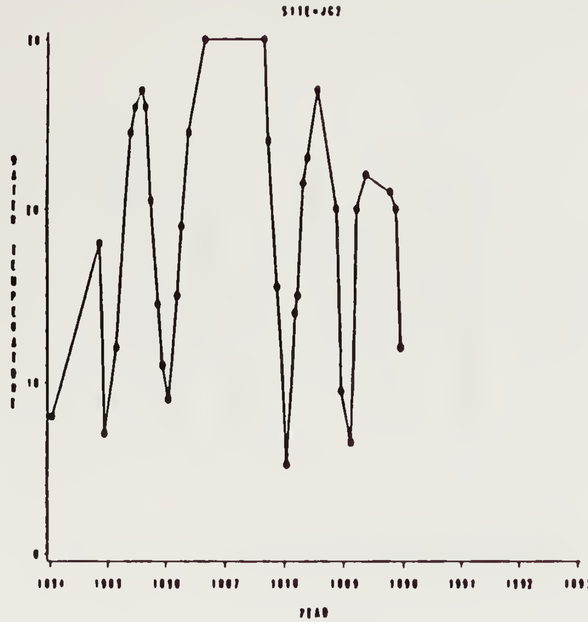
TURBIDITY (NTU)
YEAR


SITE=JC1
SPECIFIC CONDUCTANCE
YEAR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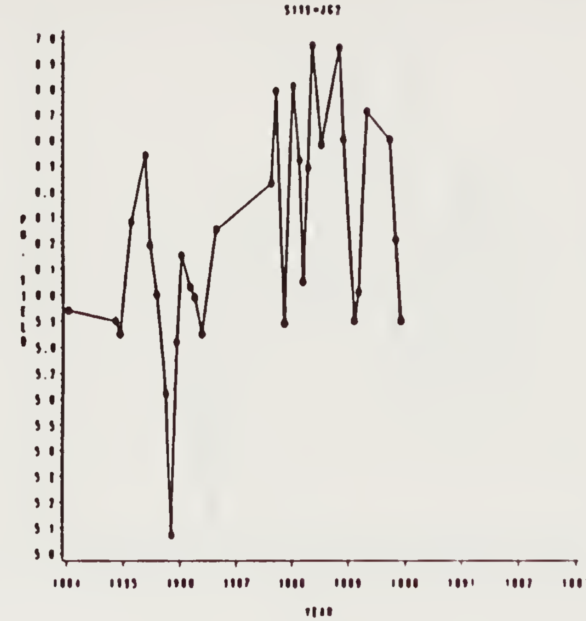
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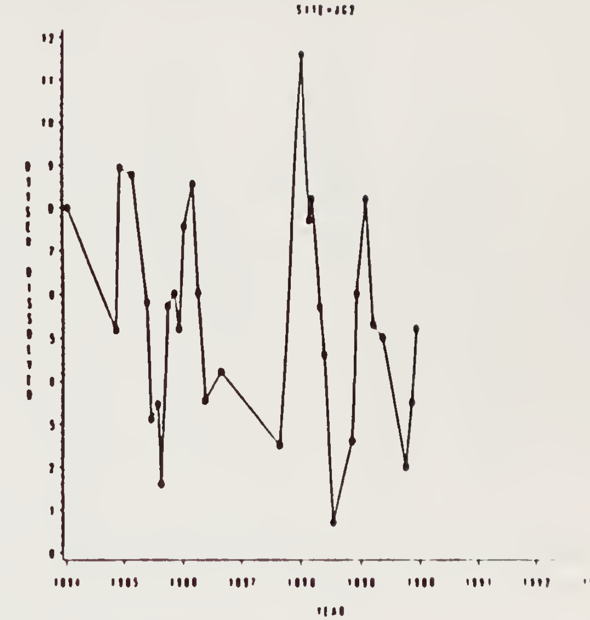
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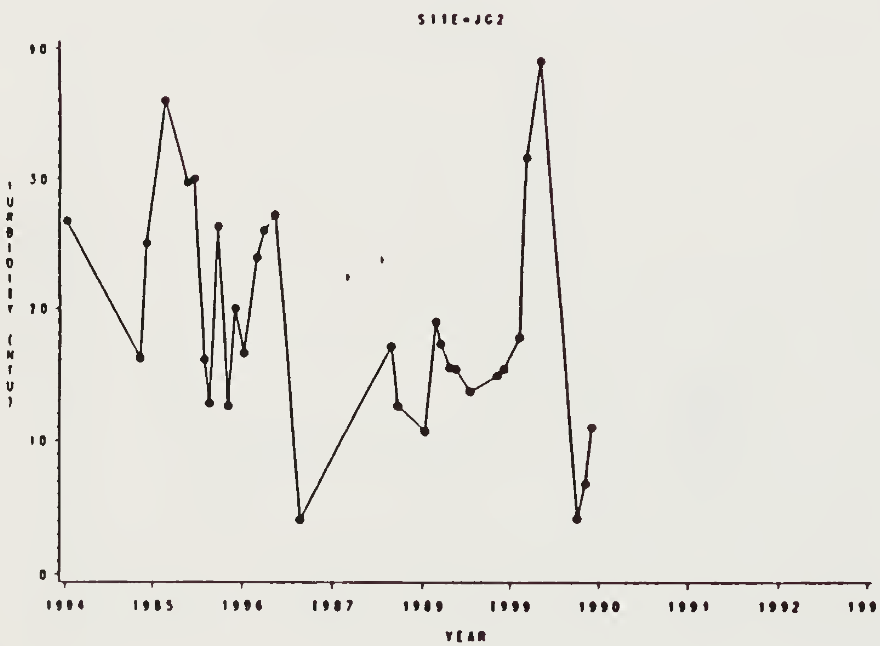
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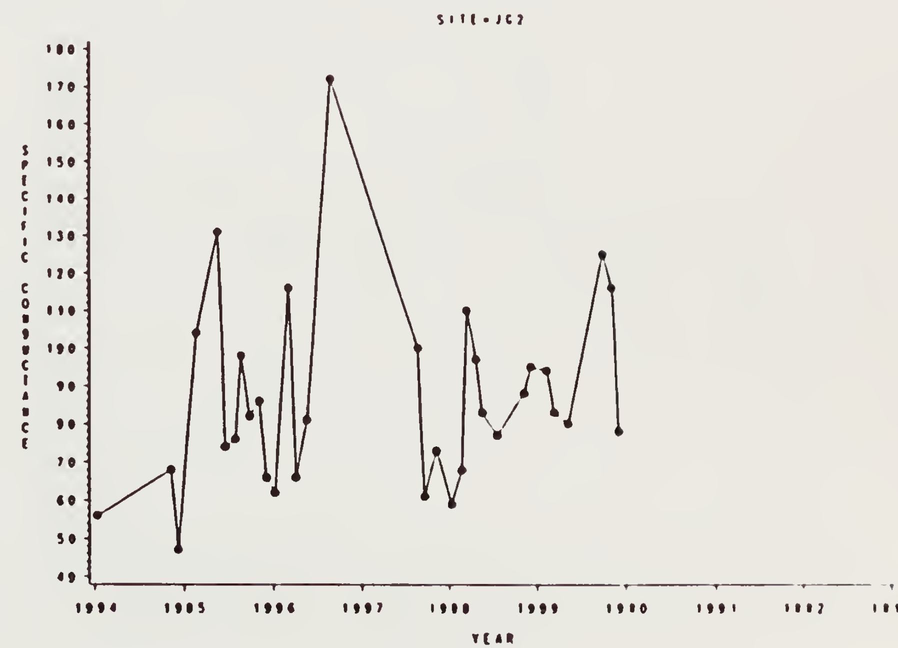
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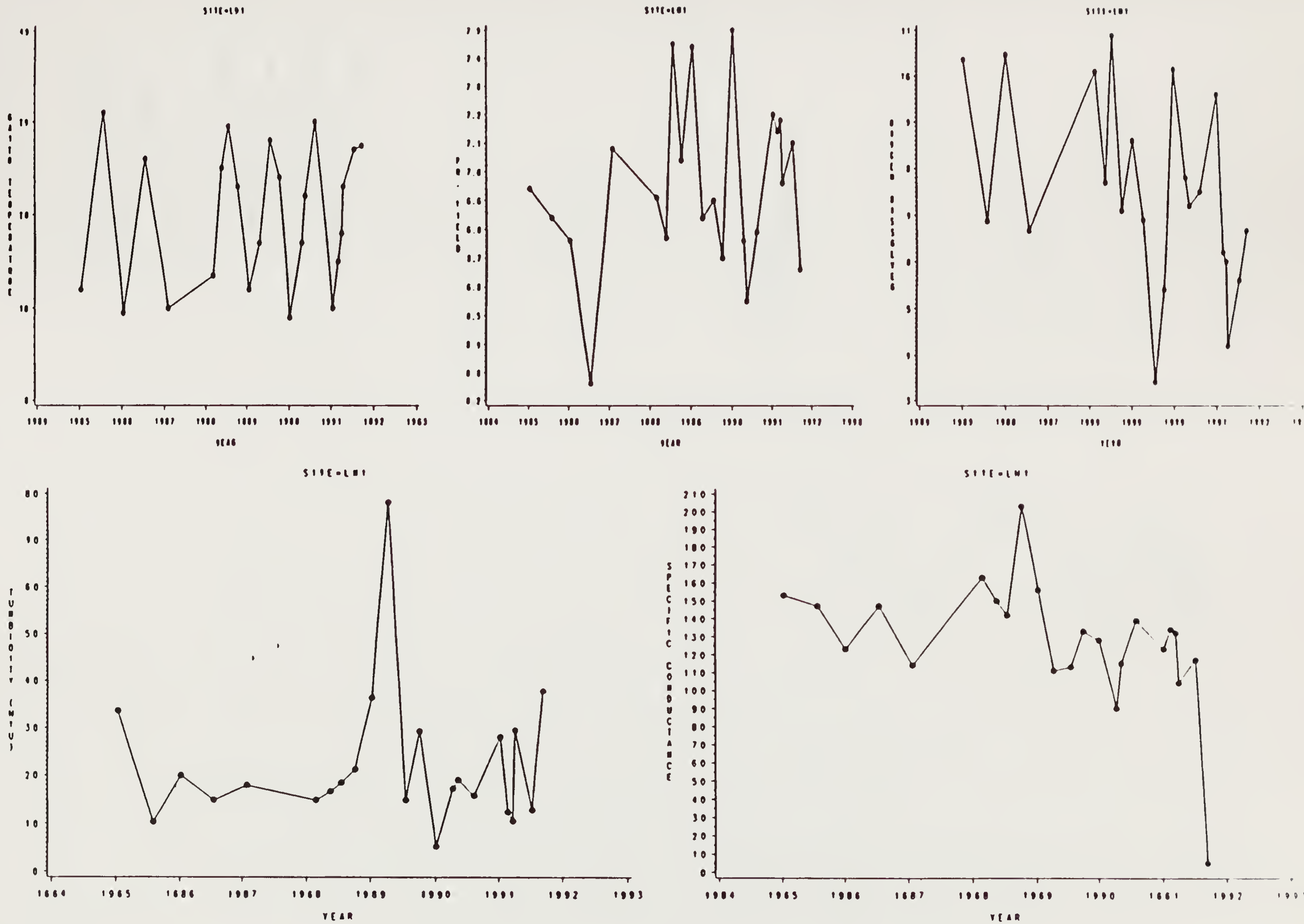
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YEAR
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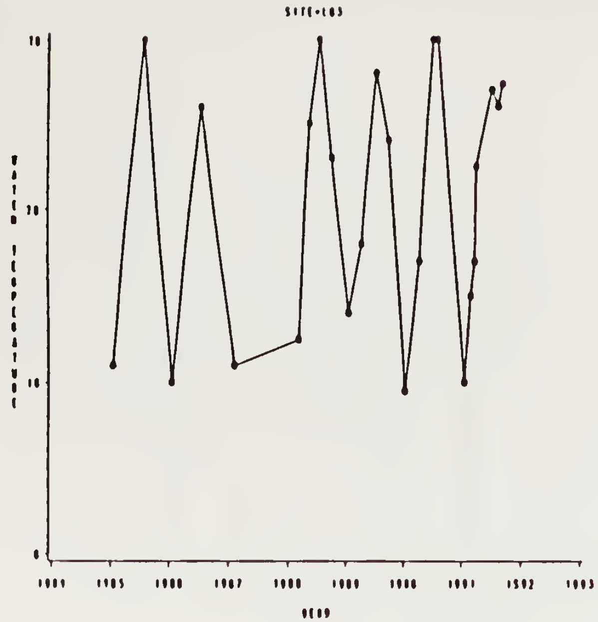
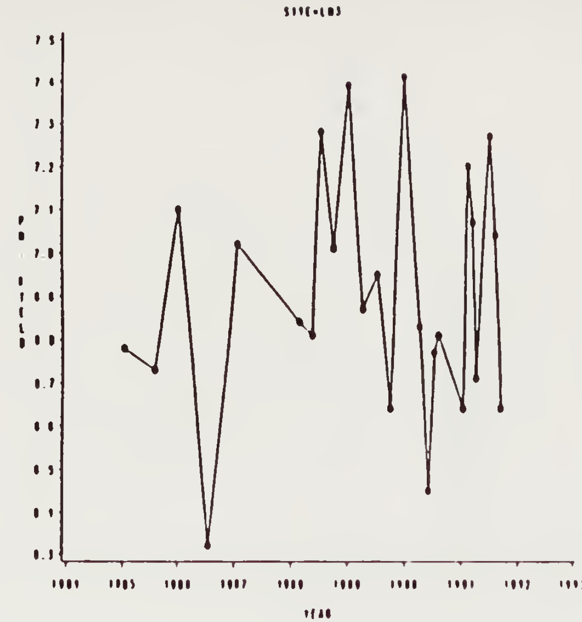
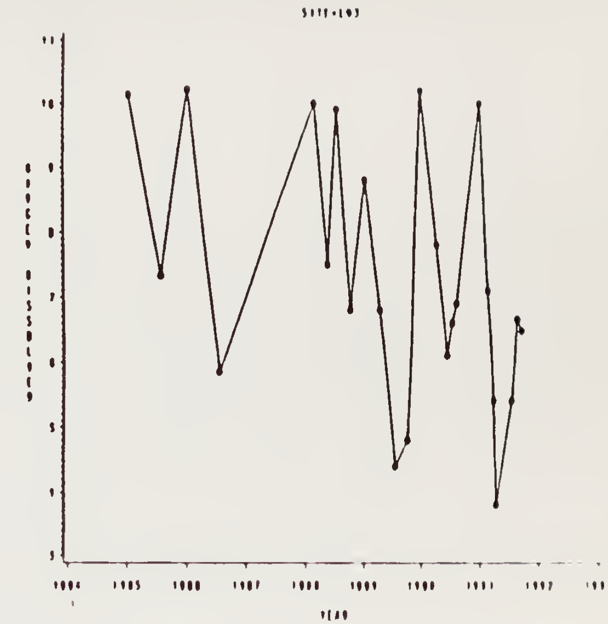
SPECIFIC CONDUCTANCE
YEAR





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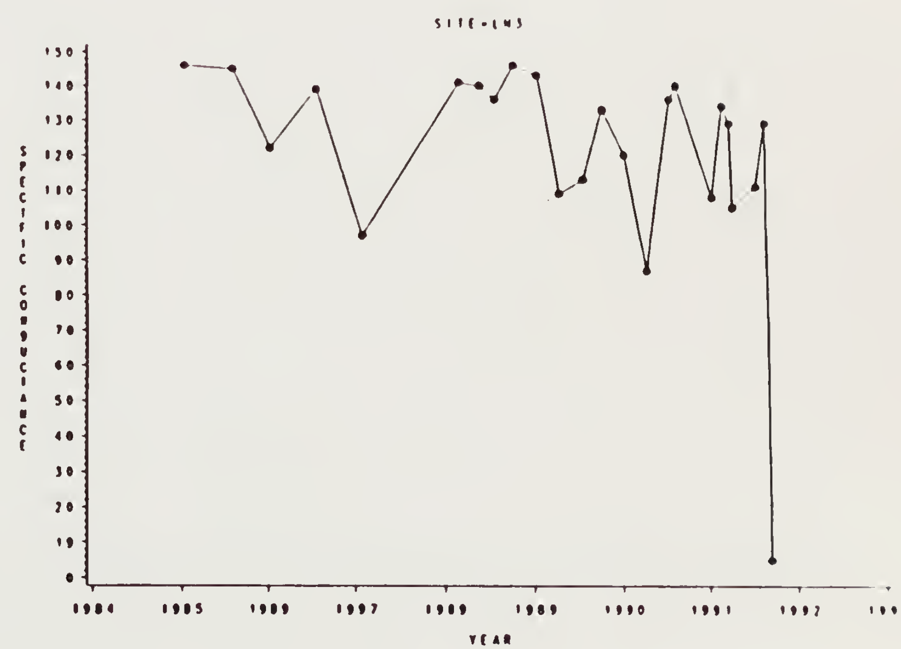
YEAR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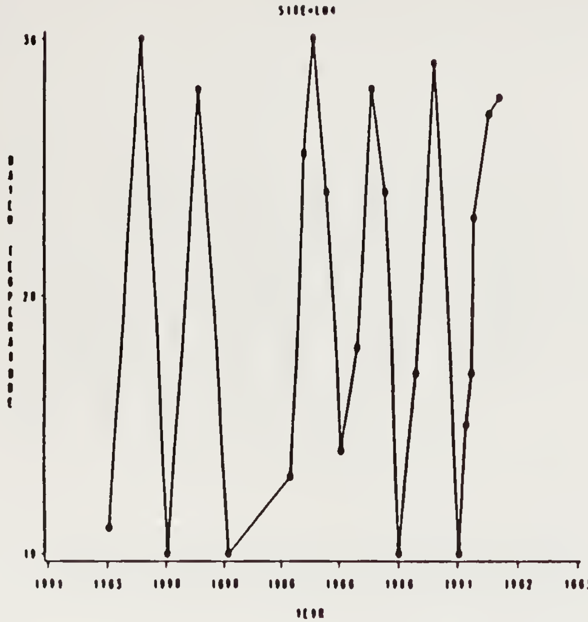
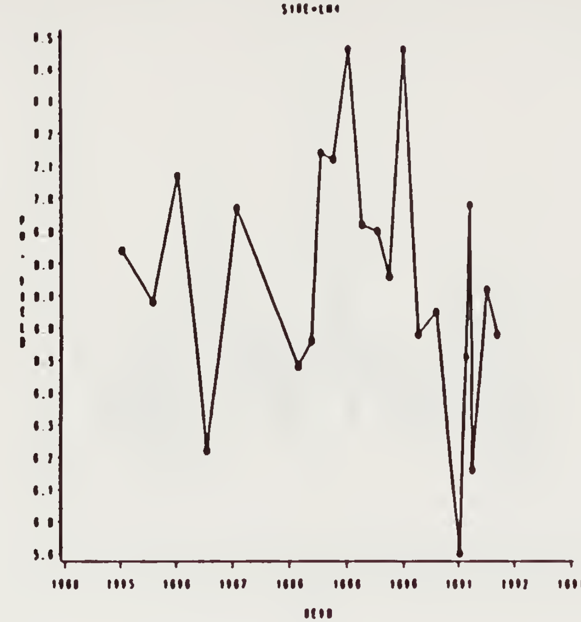
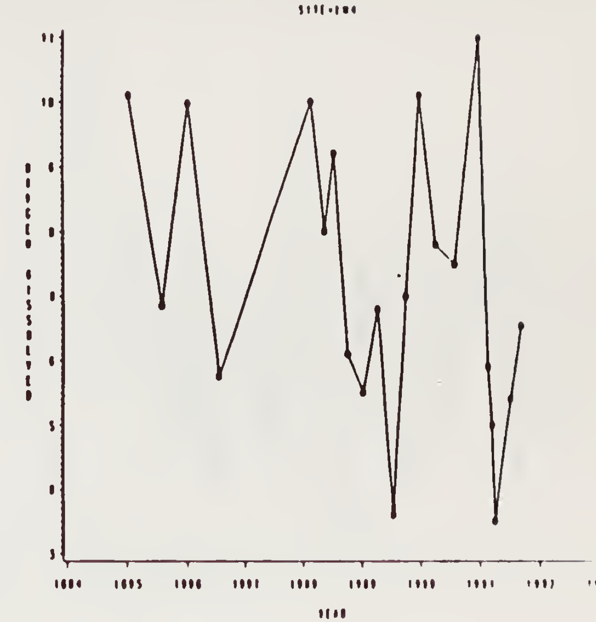
SPECIFIC CONDUCTANCE
YEAR





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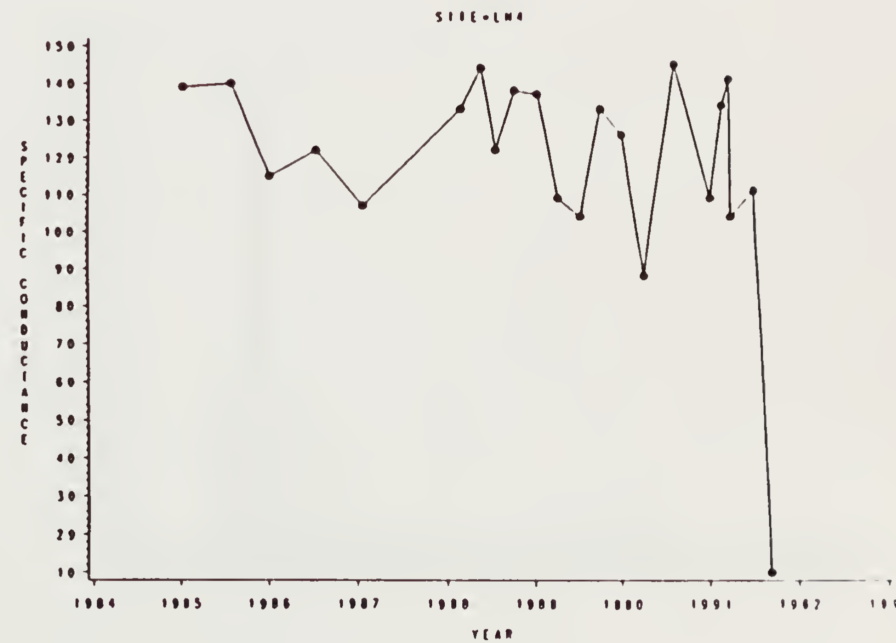
TURBIDITY (NTU)
YEAR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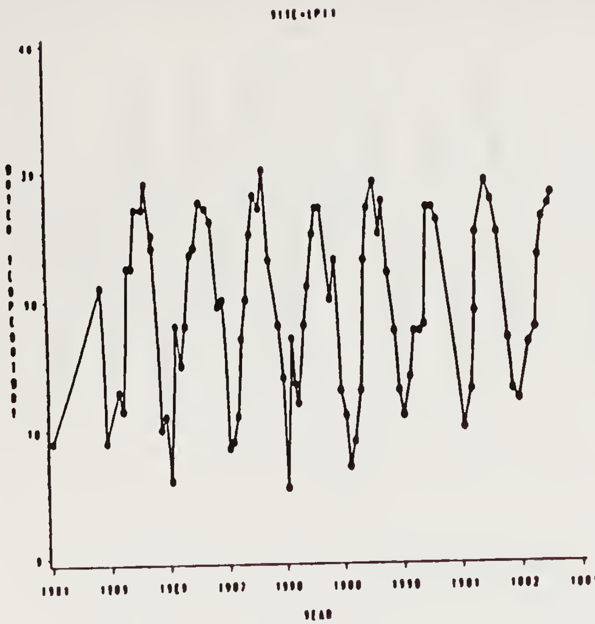

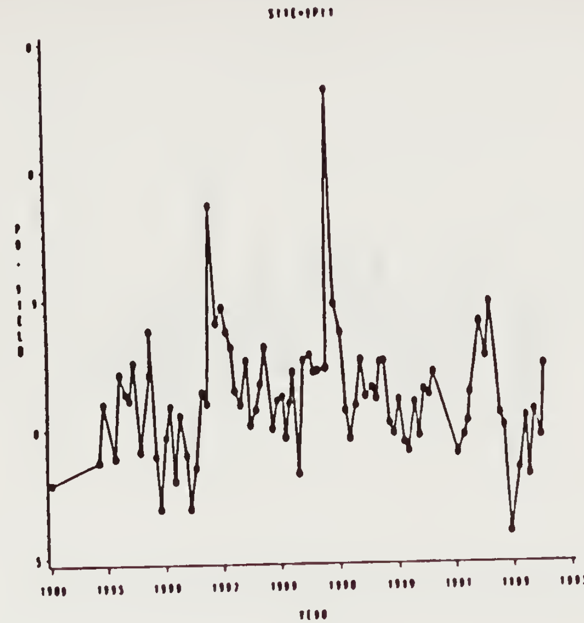

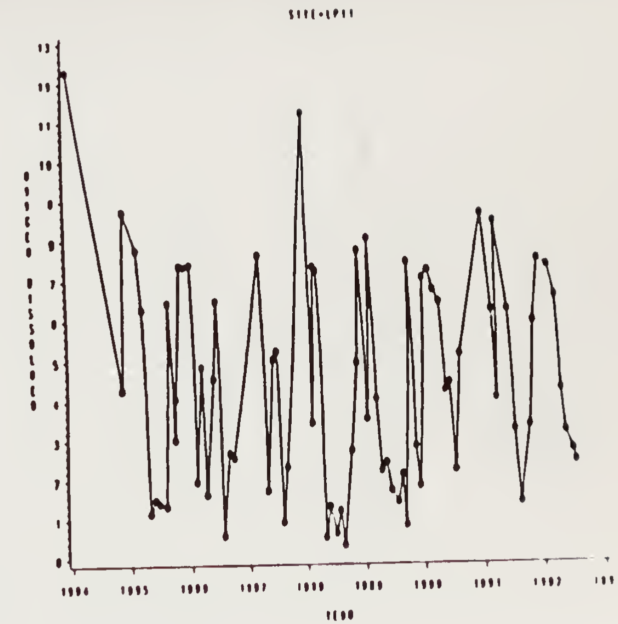


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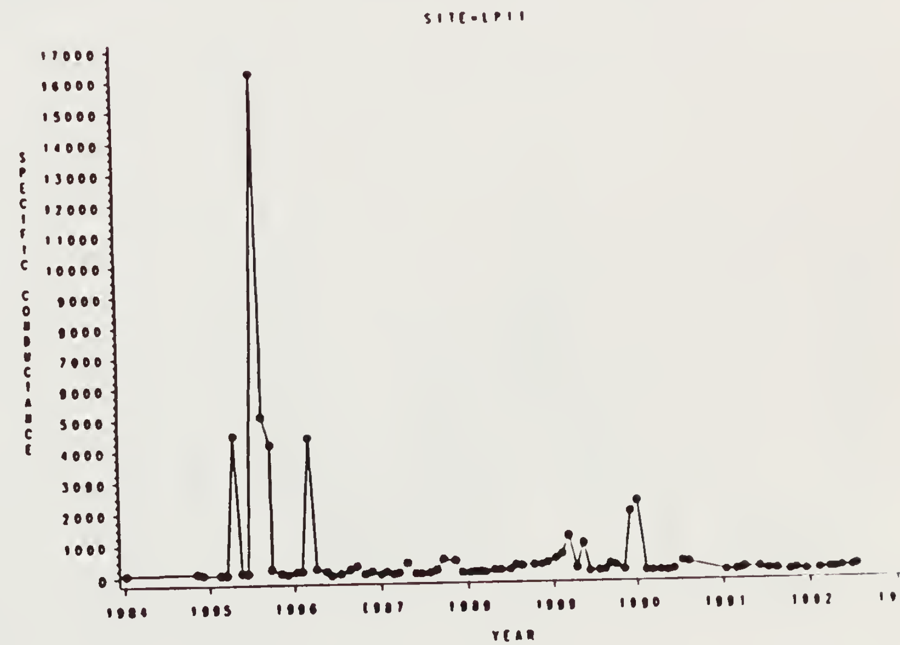
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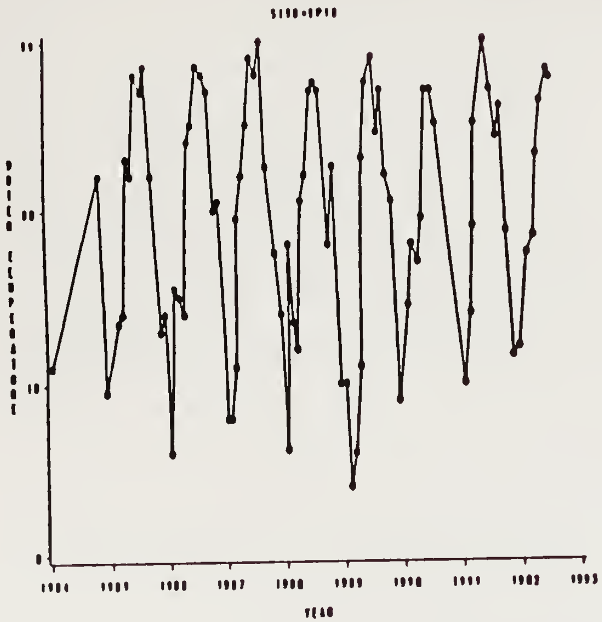
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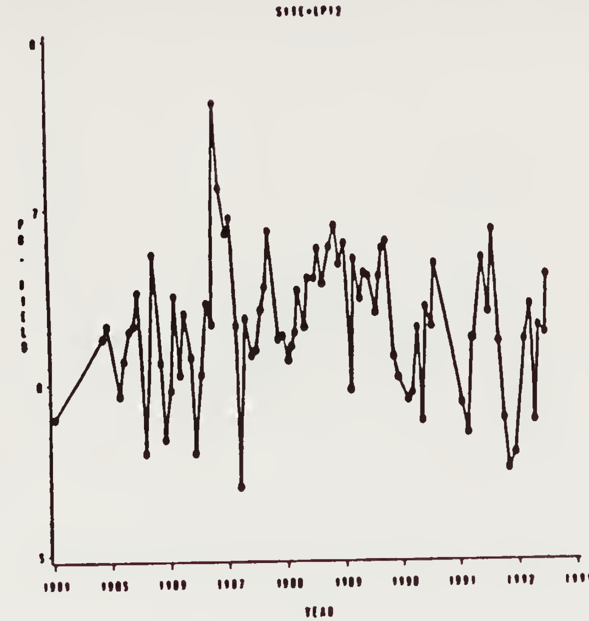
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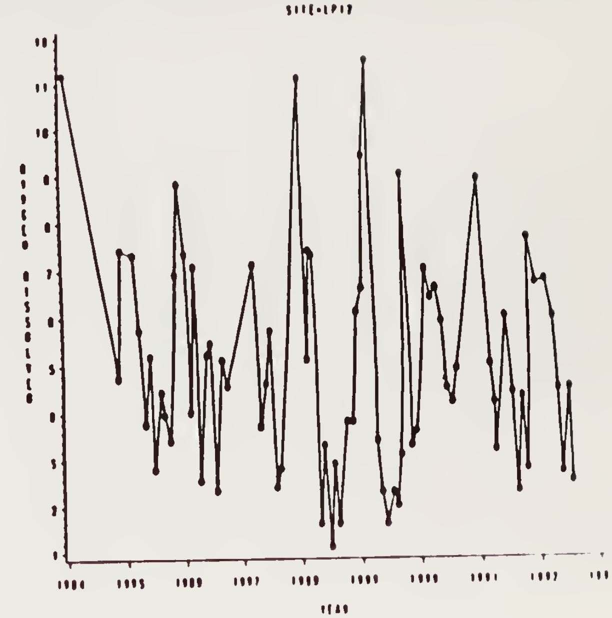
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YEAR


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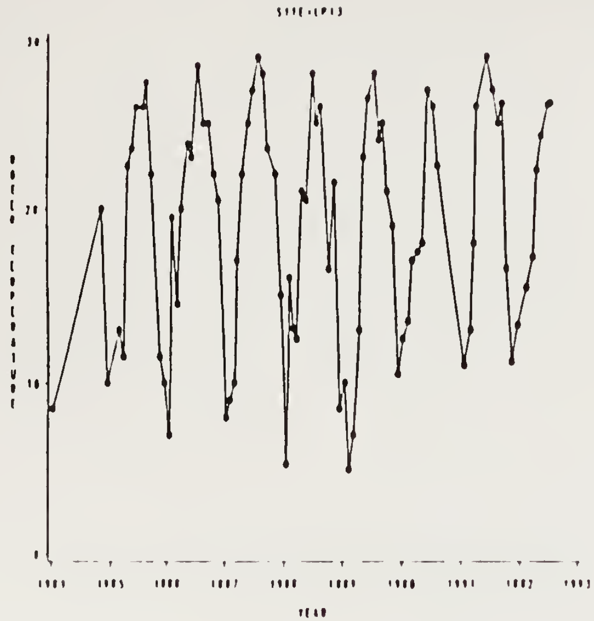
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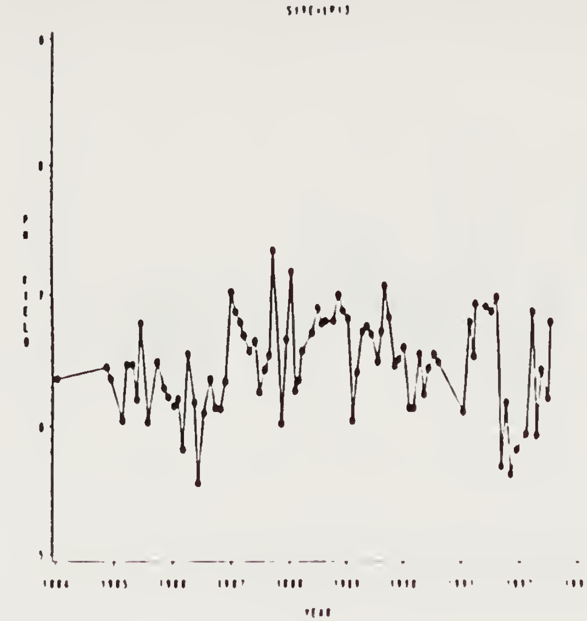
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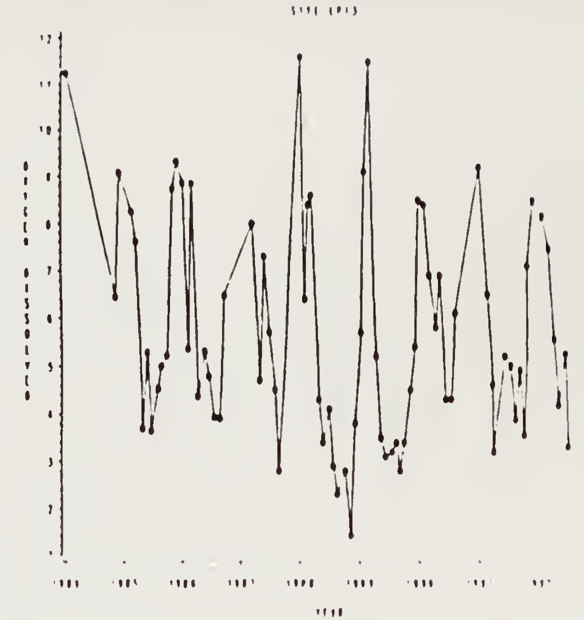


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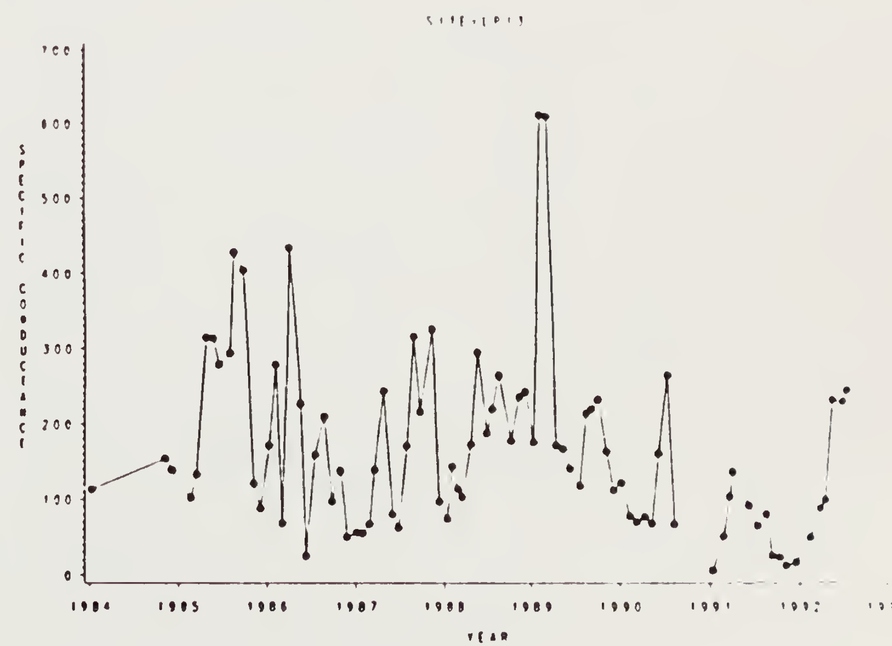
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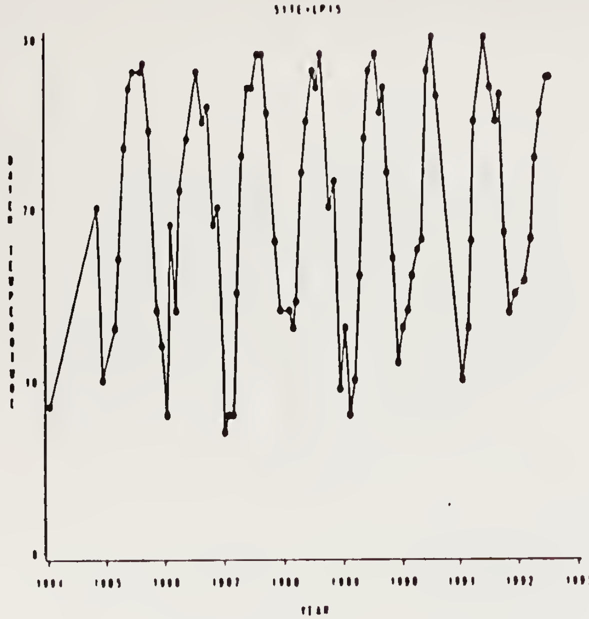
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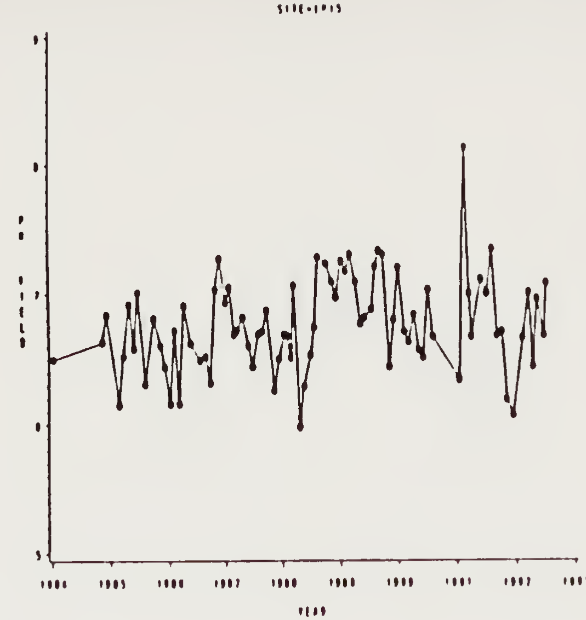
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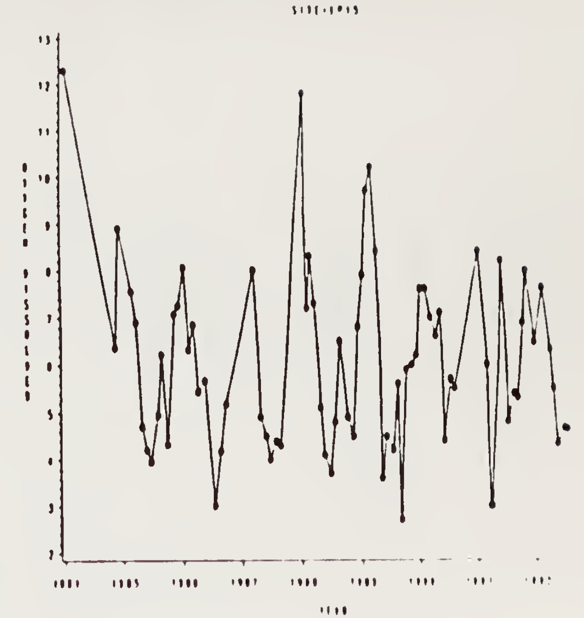
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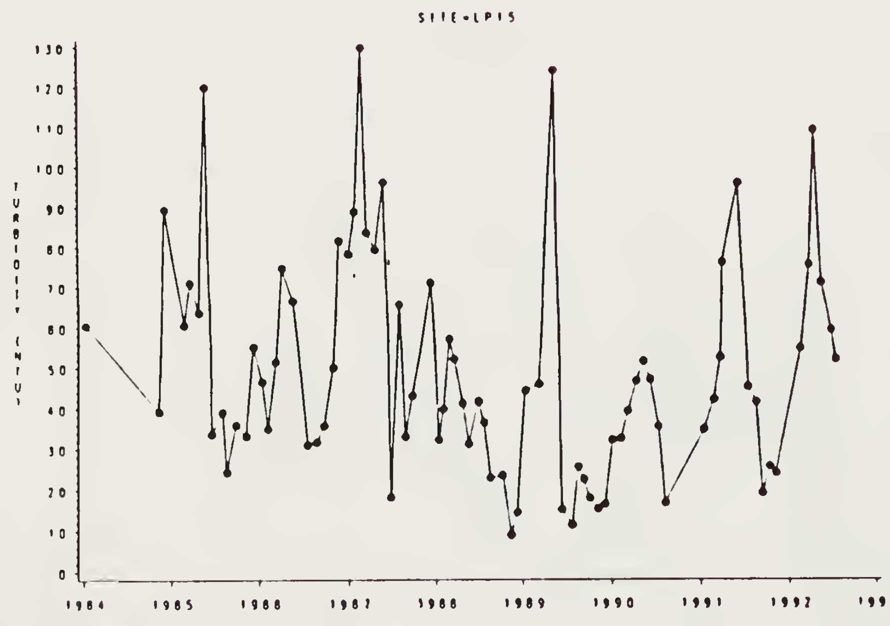
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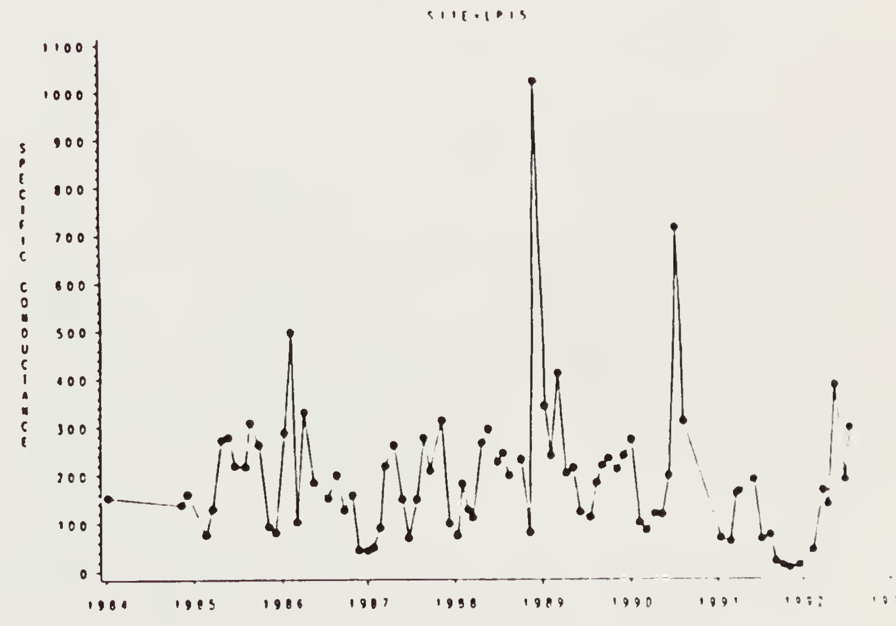
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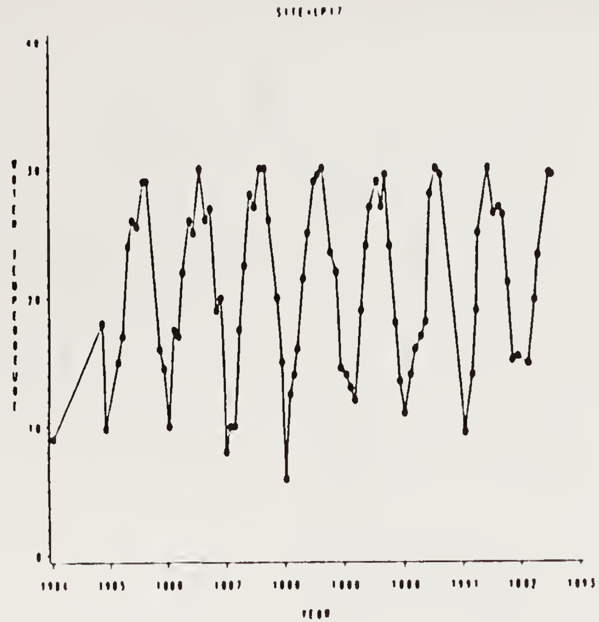
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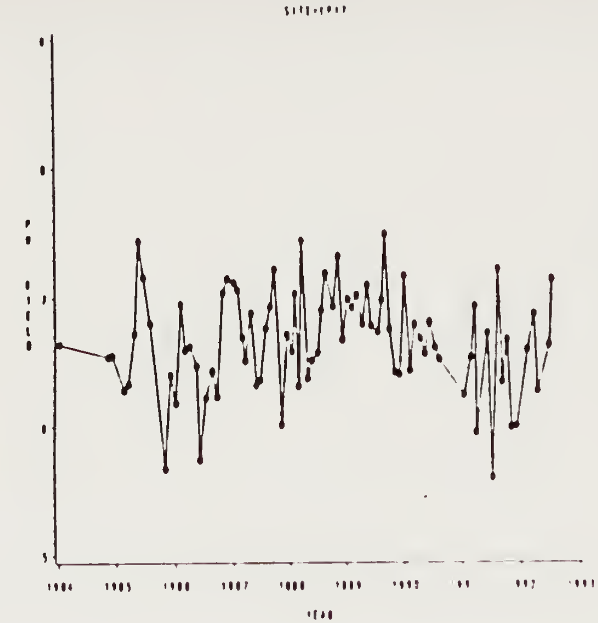
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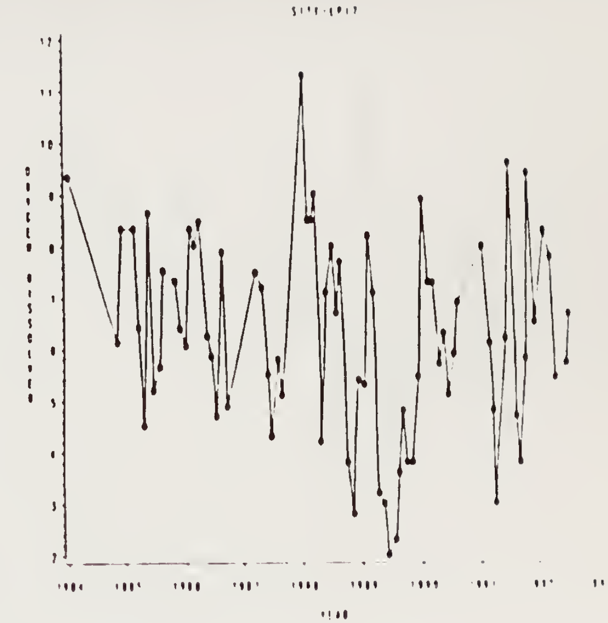
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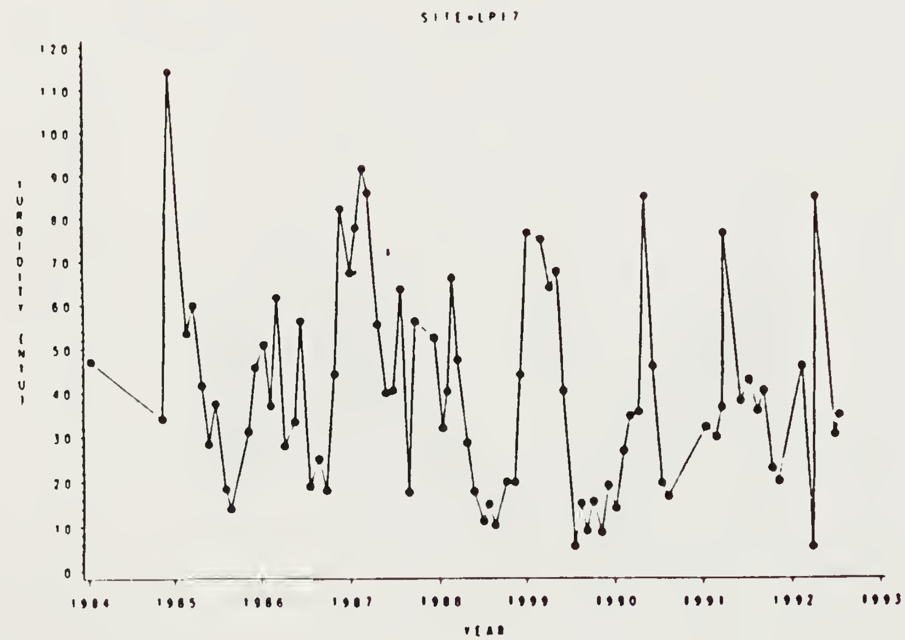
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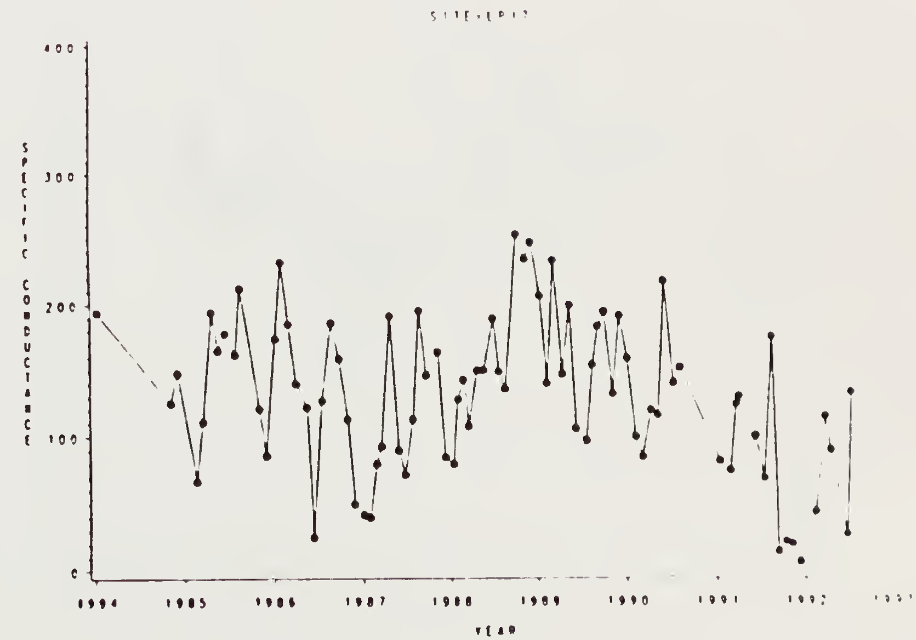
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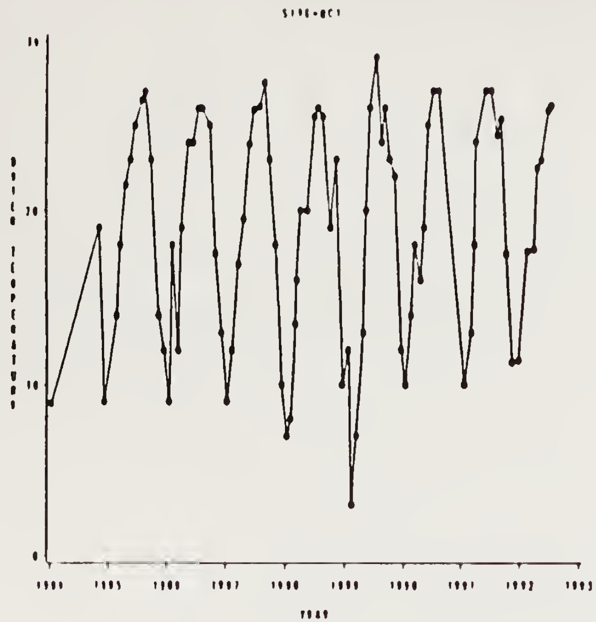

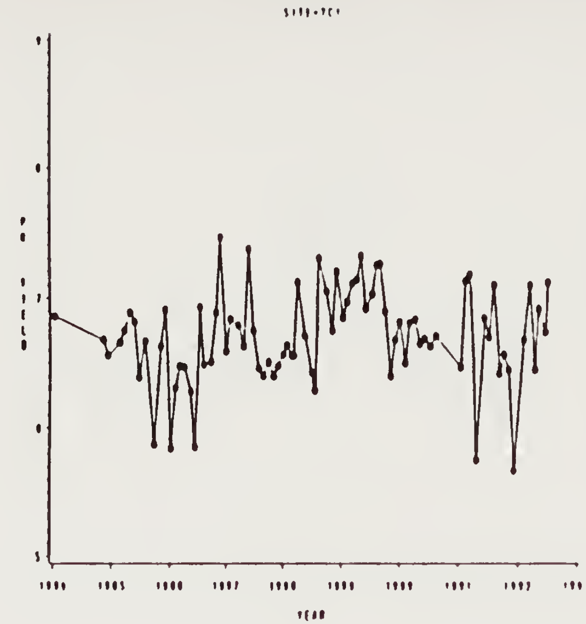

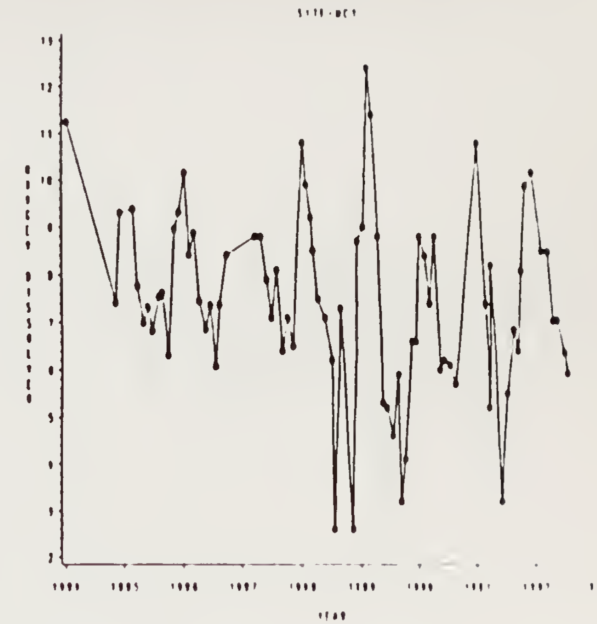

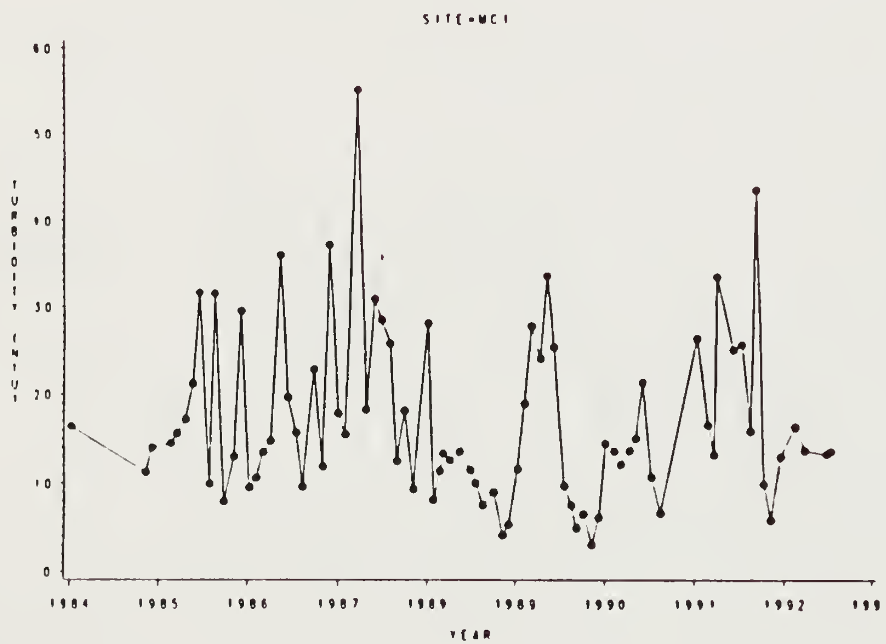
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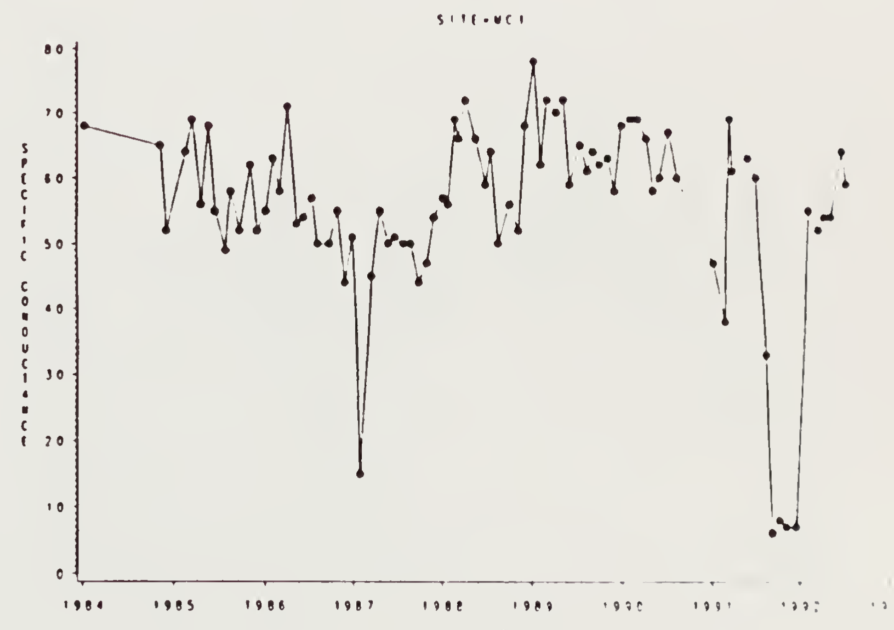
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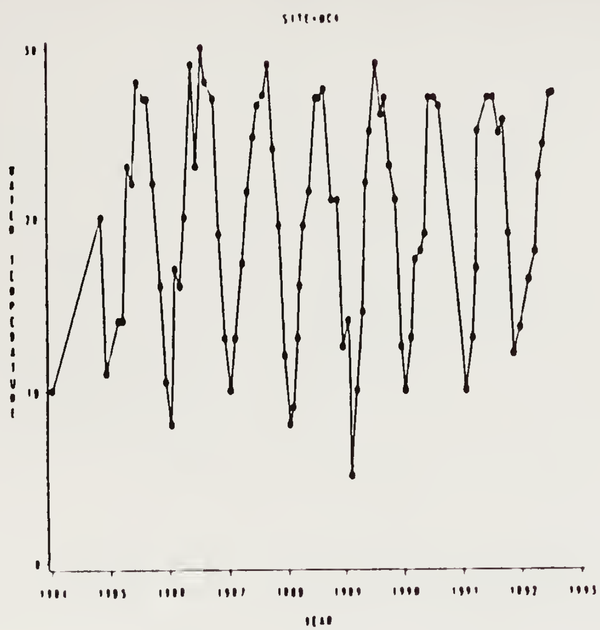
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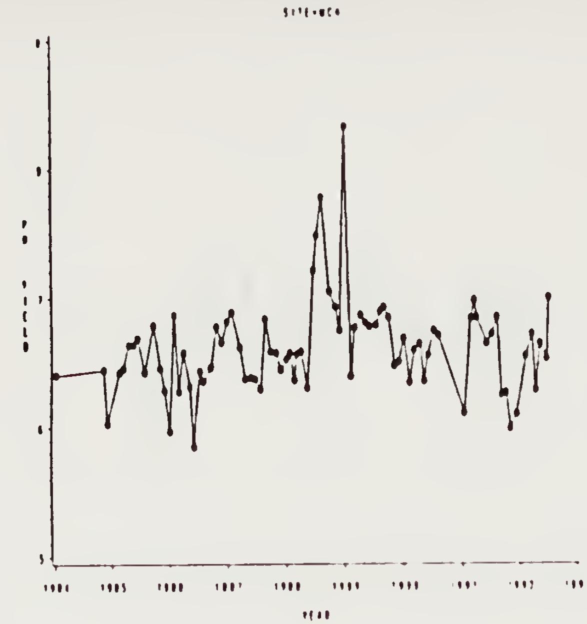

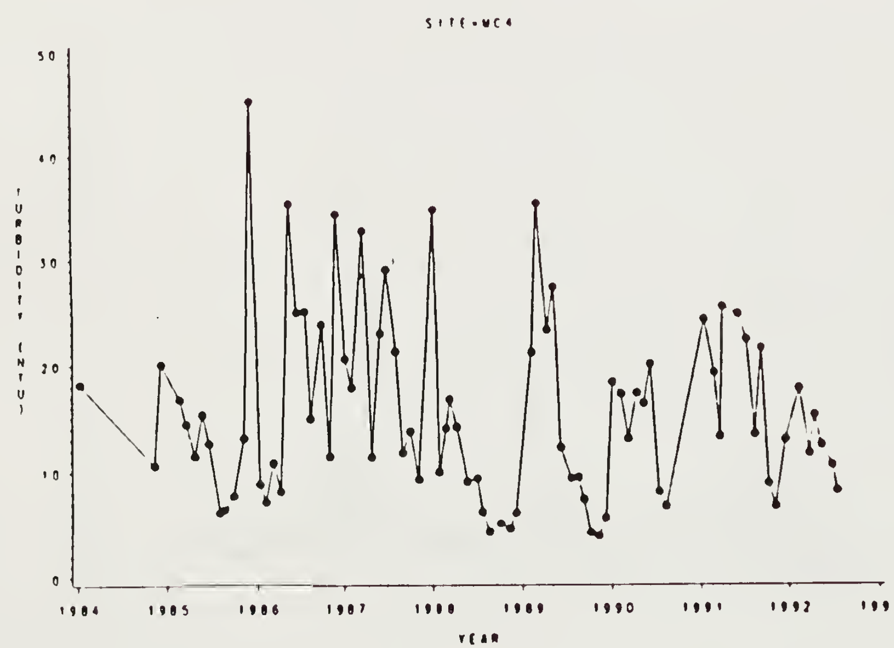
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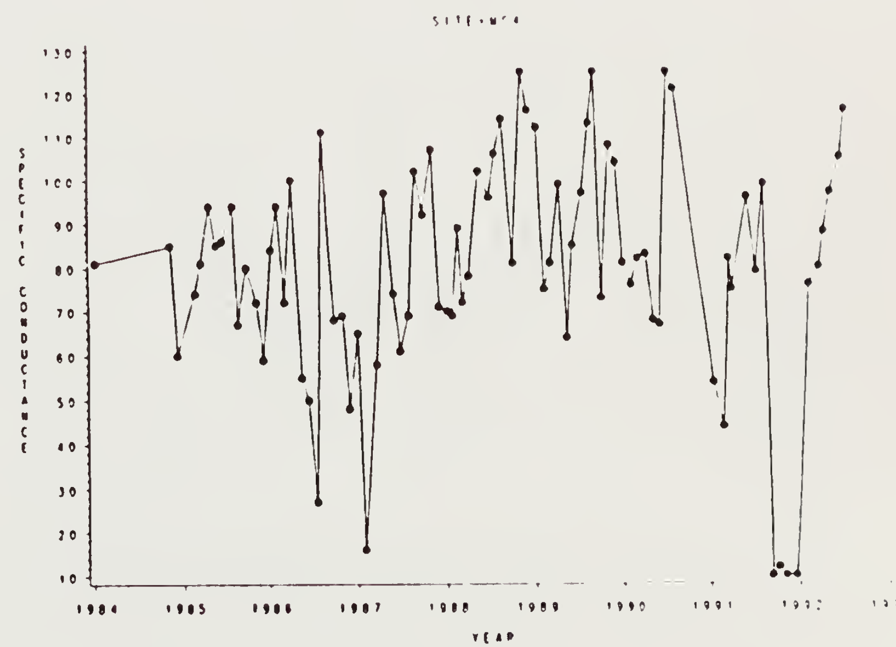
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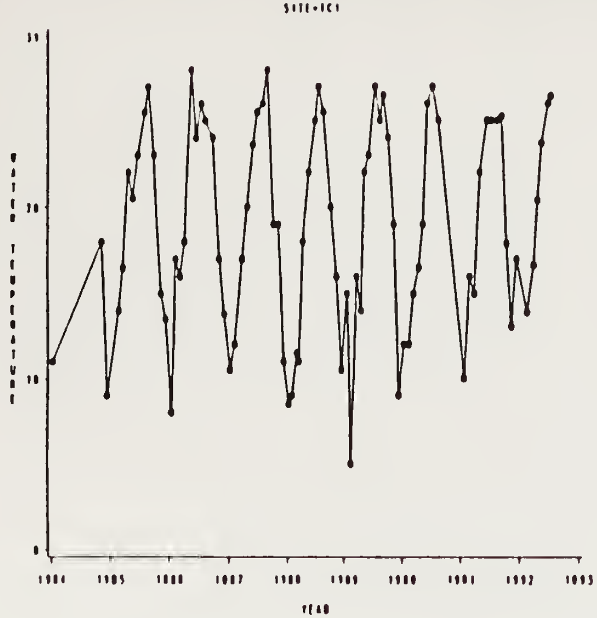
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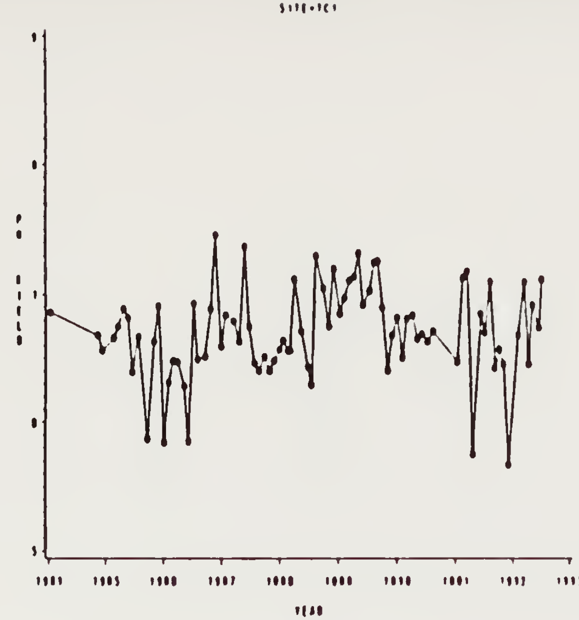
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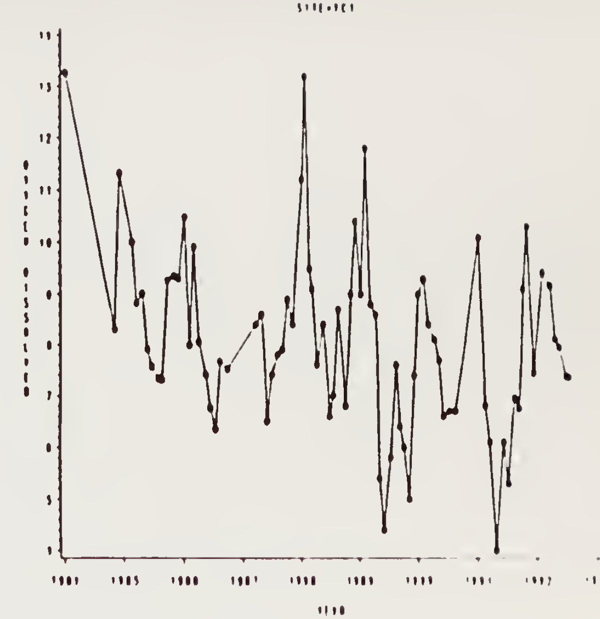
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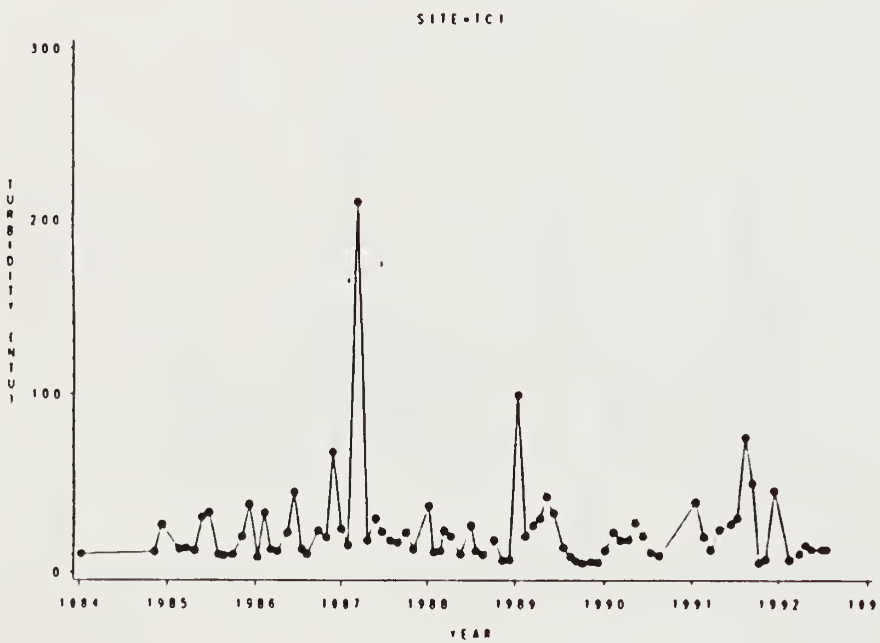
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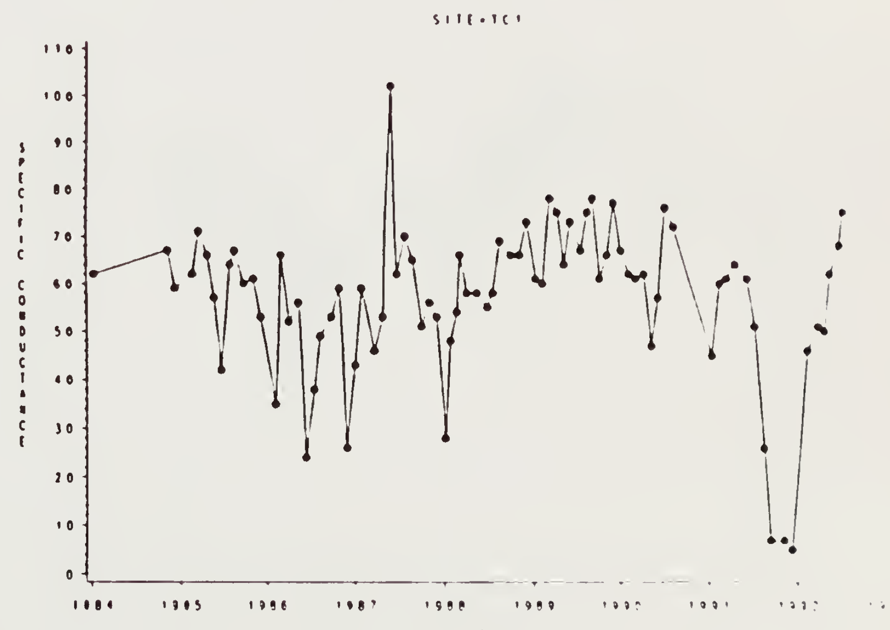
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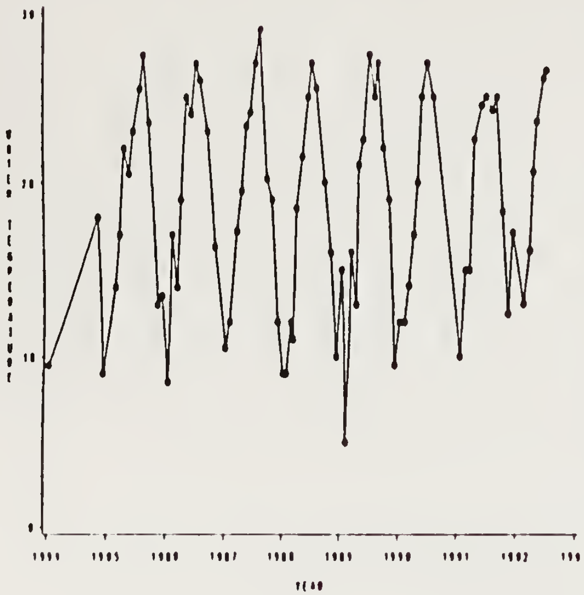

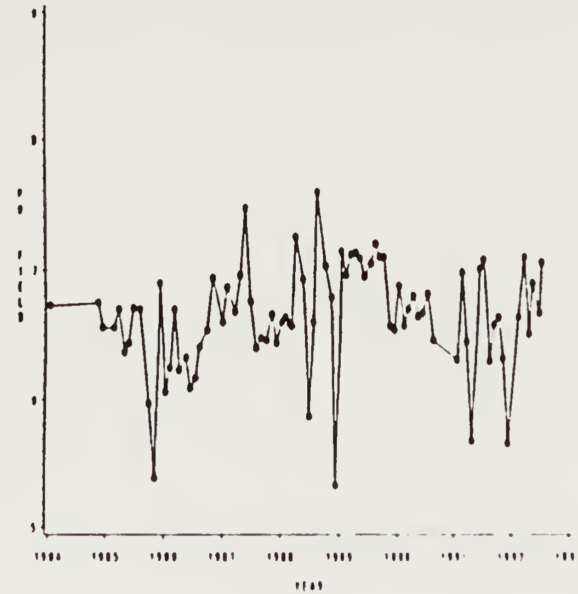

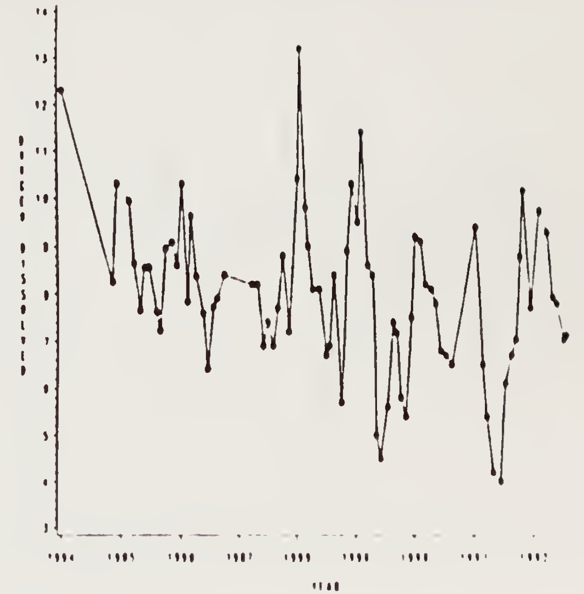

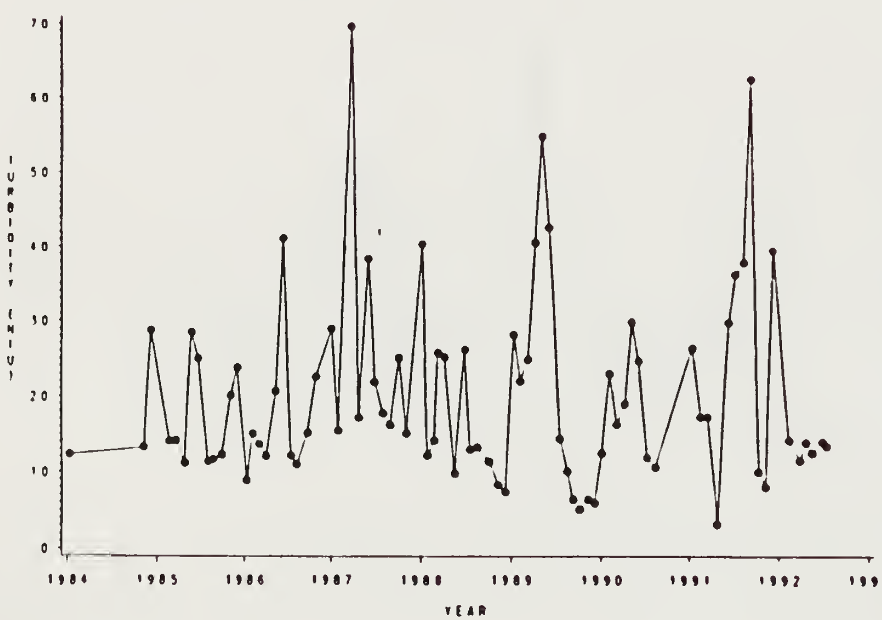
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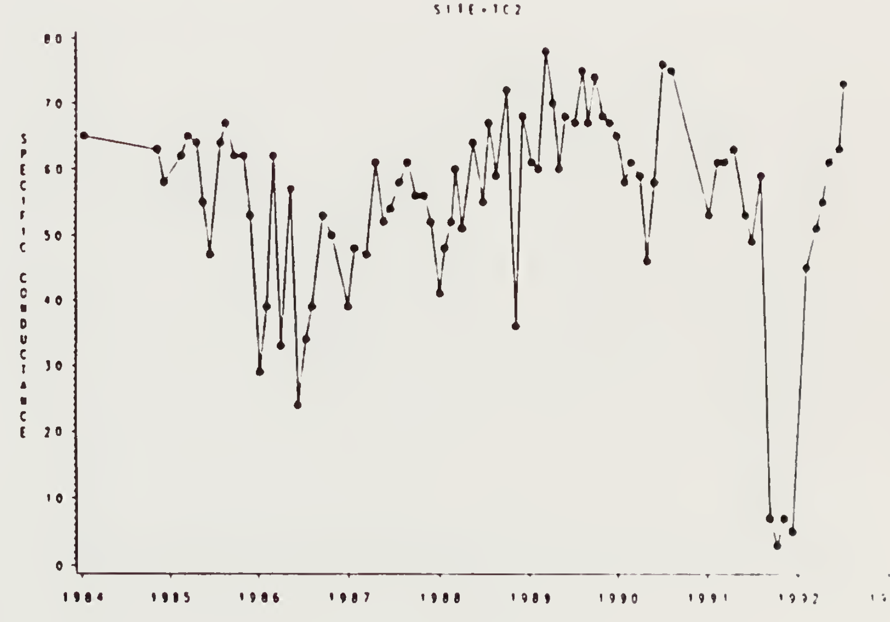
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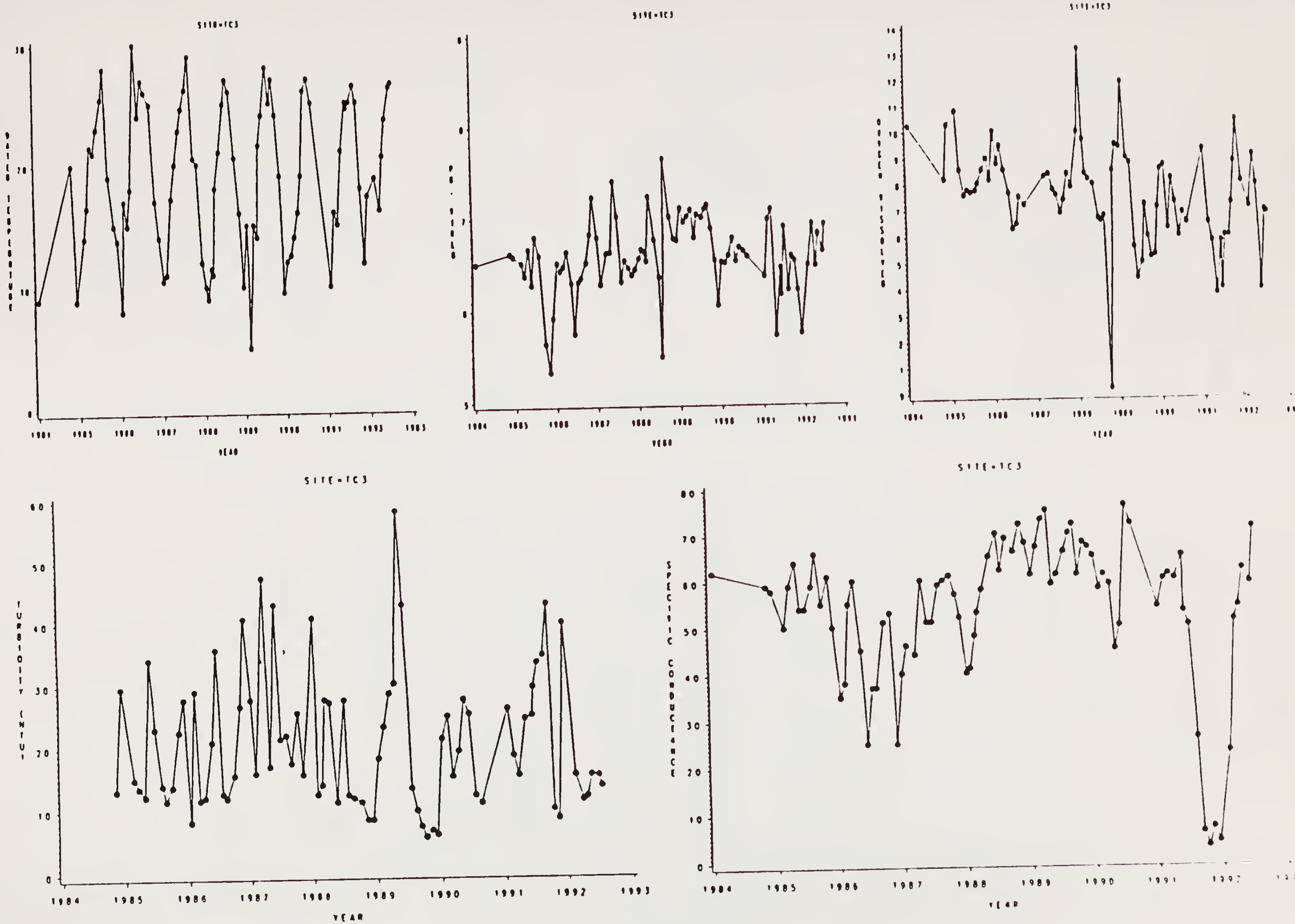
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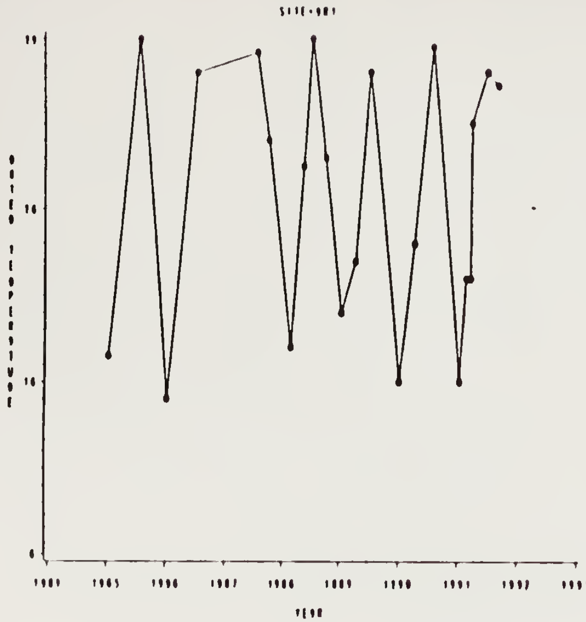

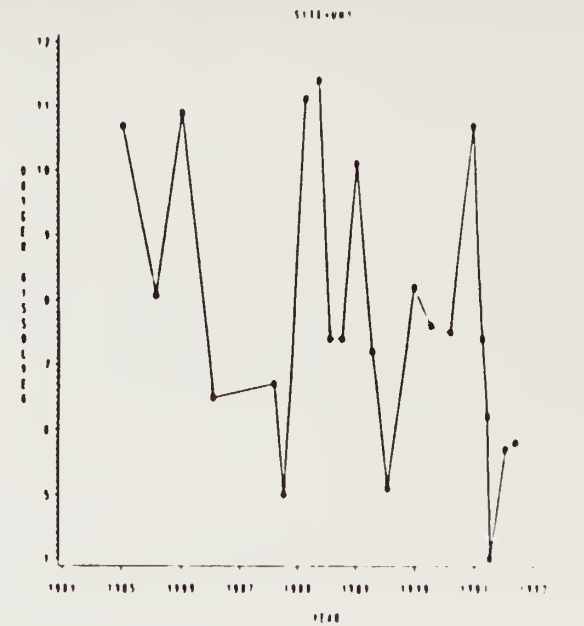

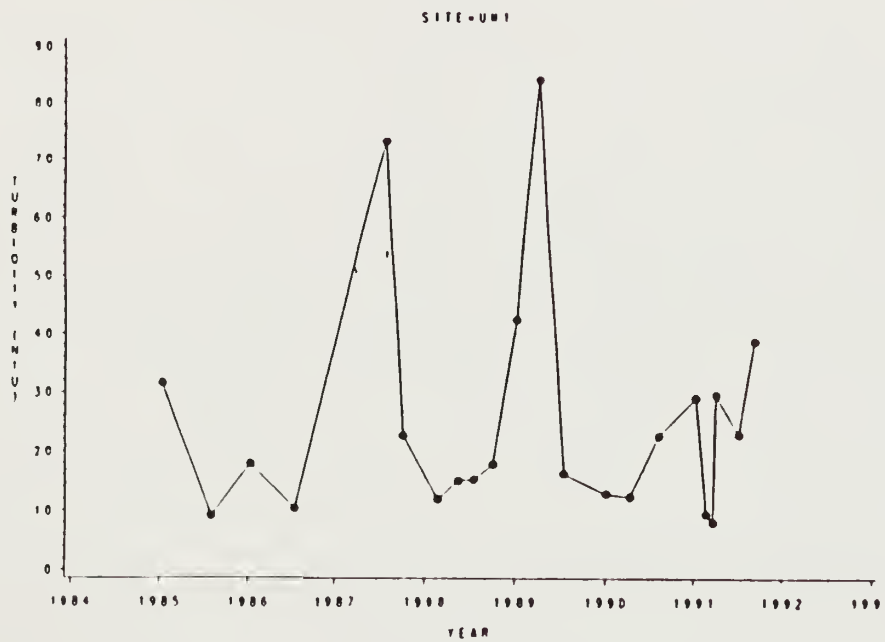
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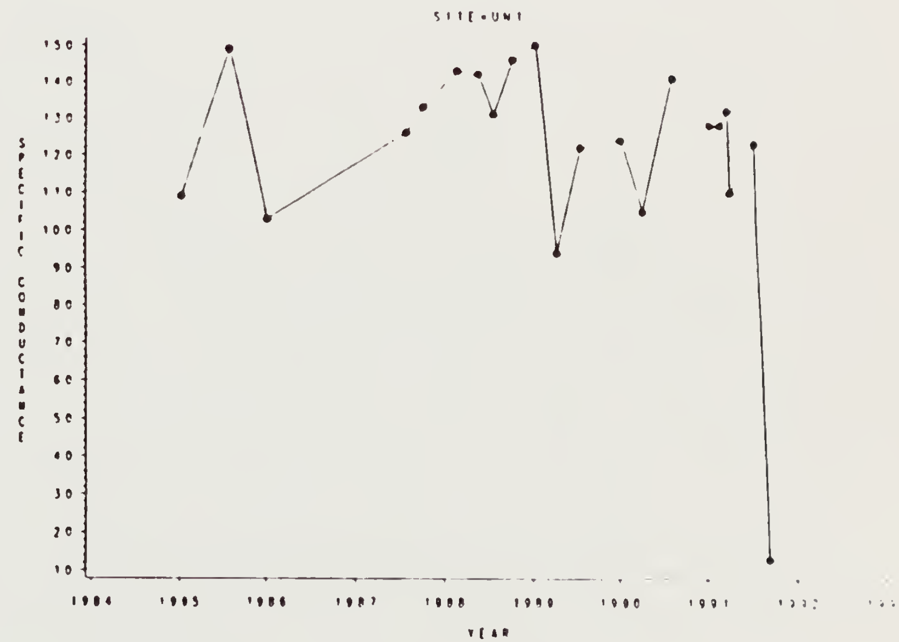
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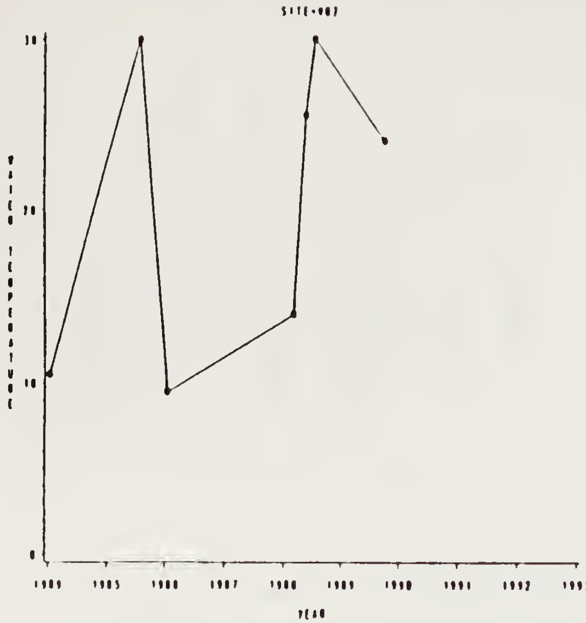

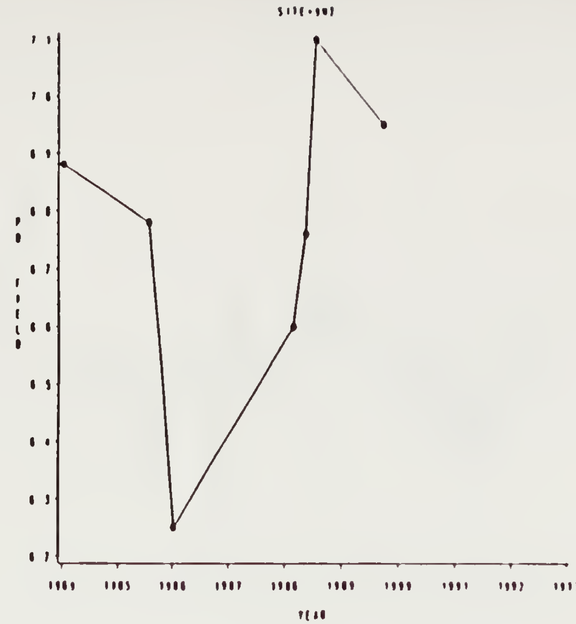

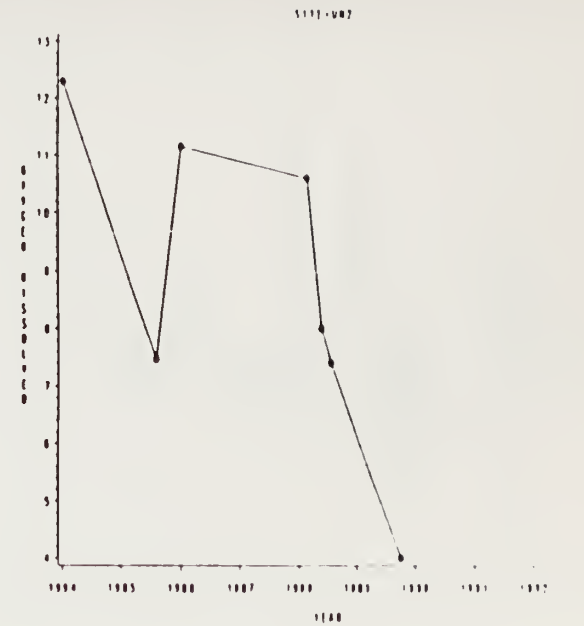

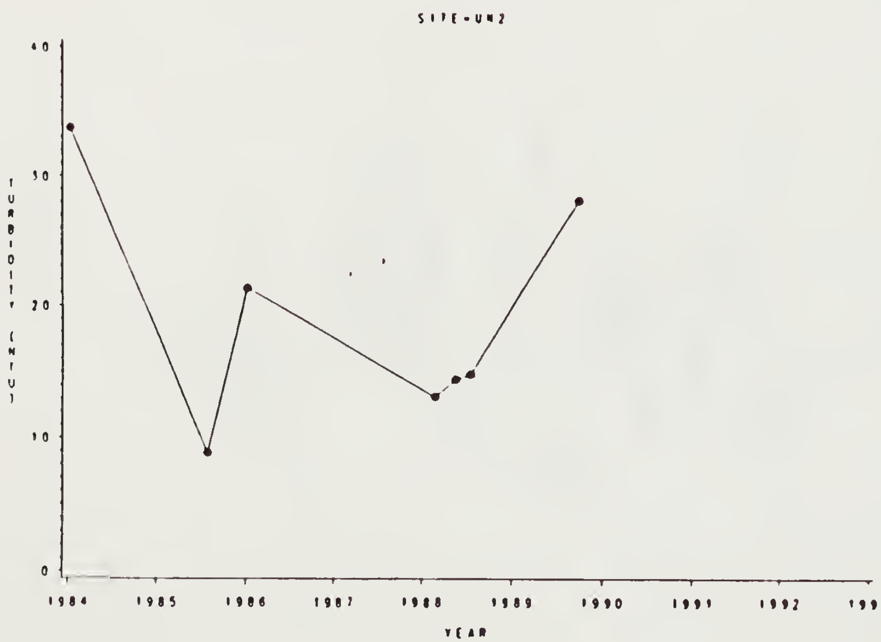
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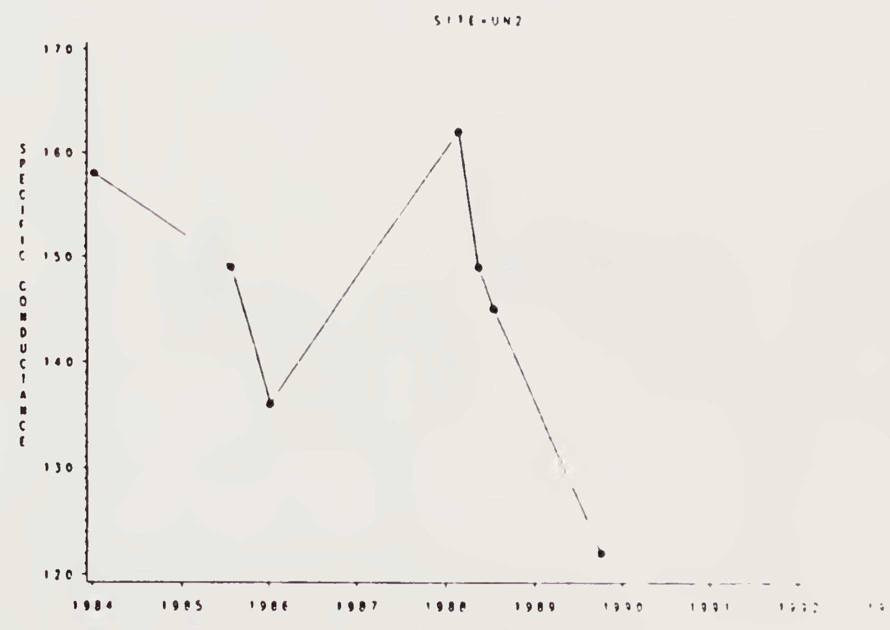
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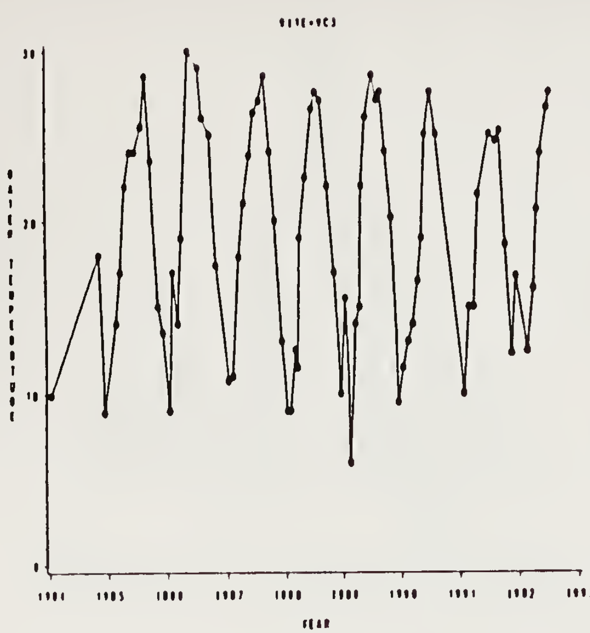

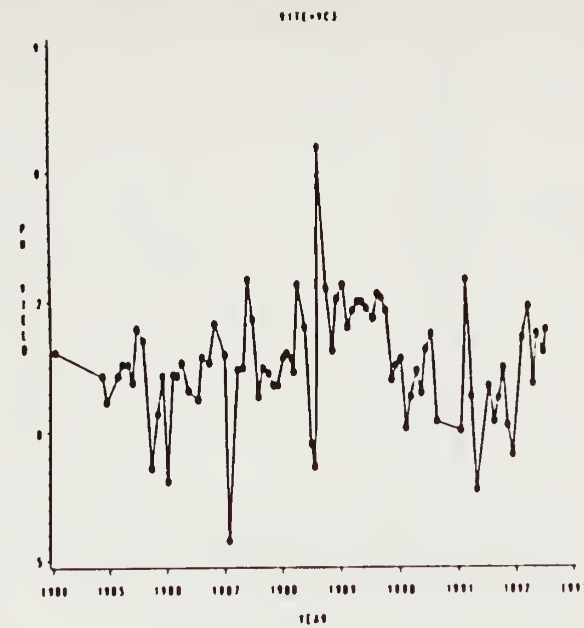

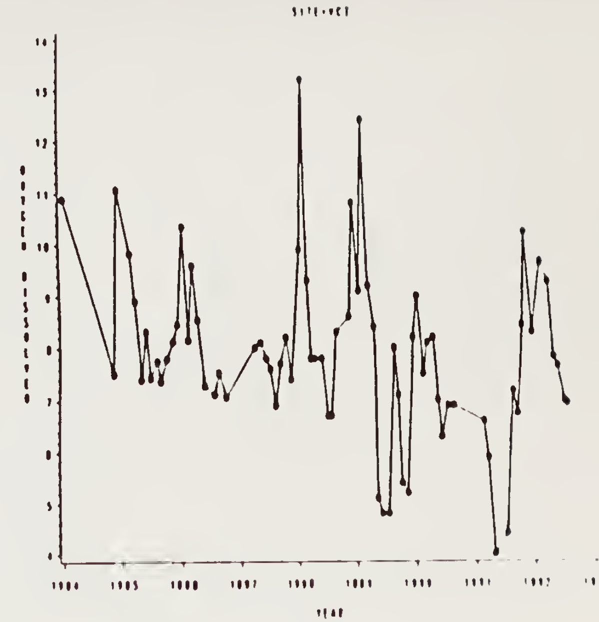

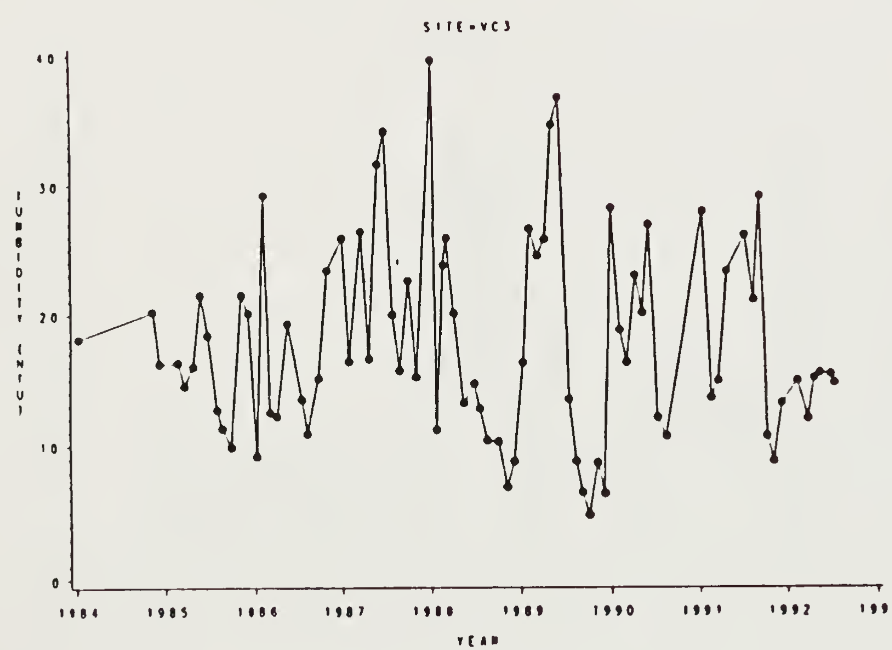
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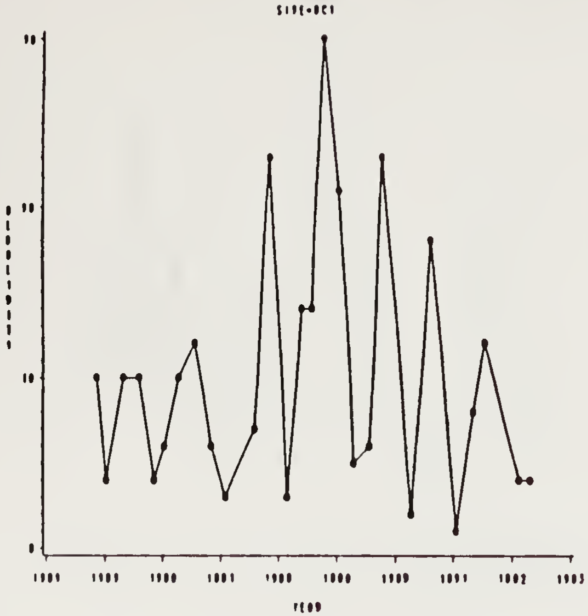

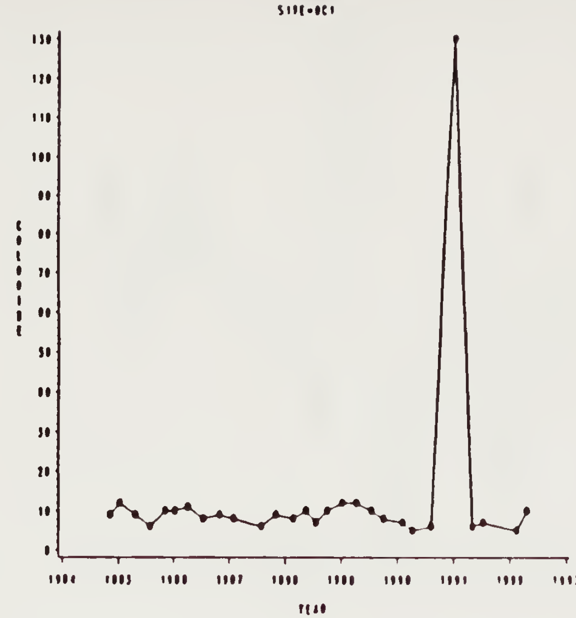

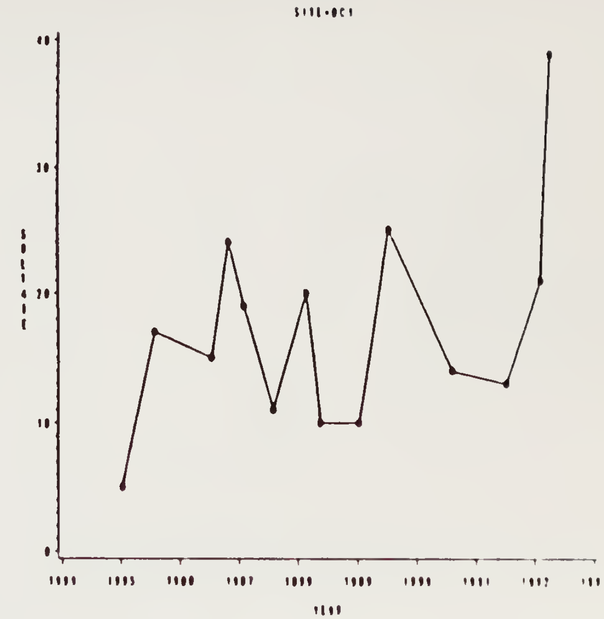

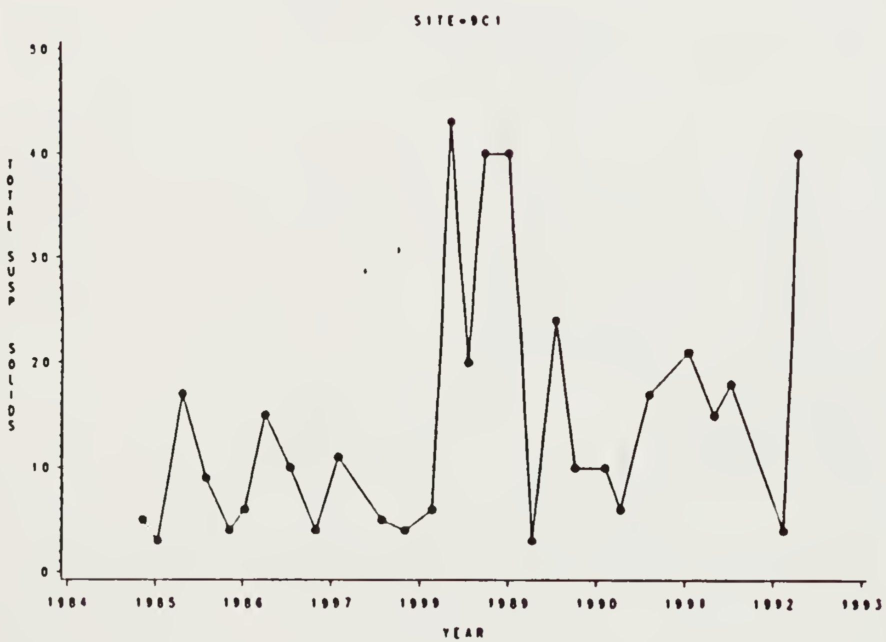
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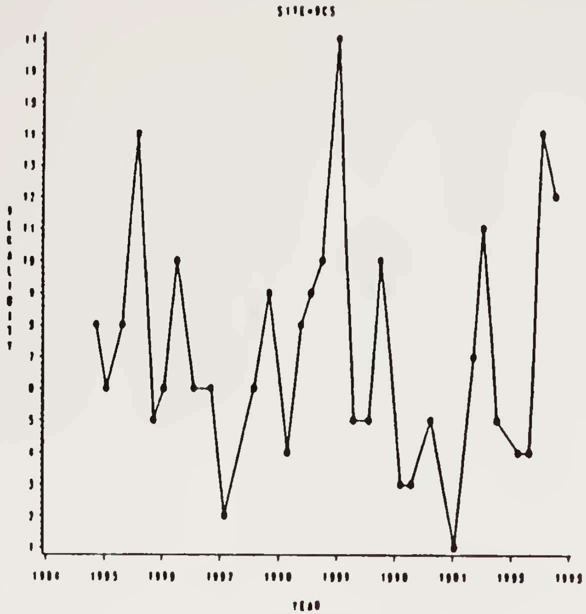
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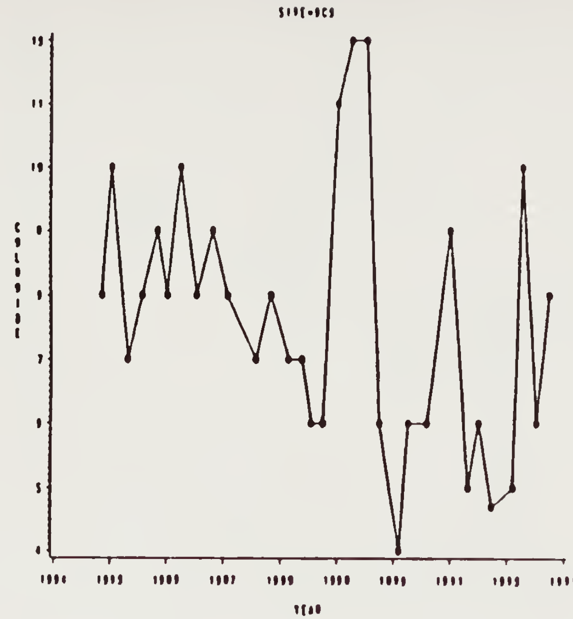
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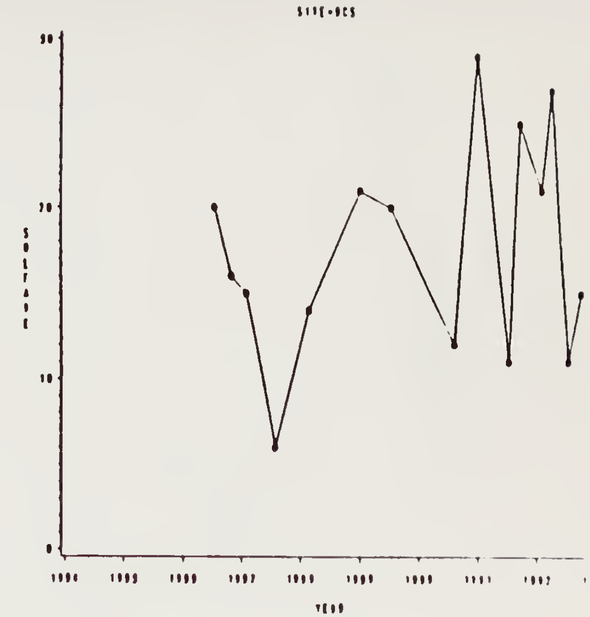
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SITE=BCS
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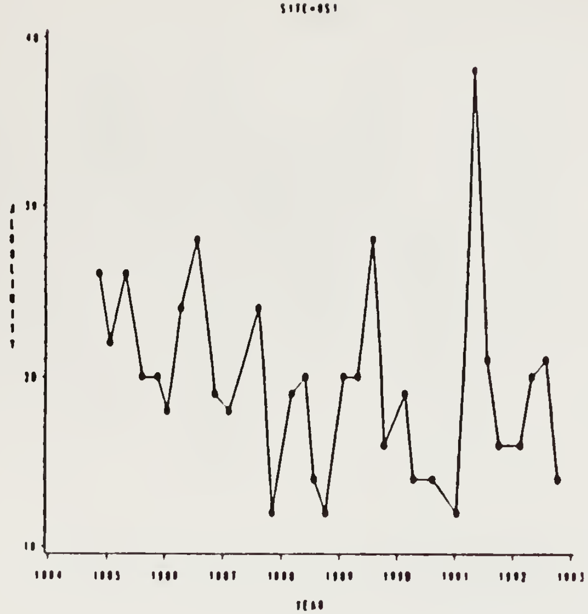
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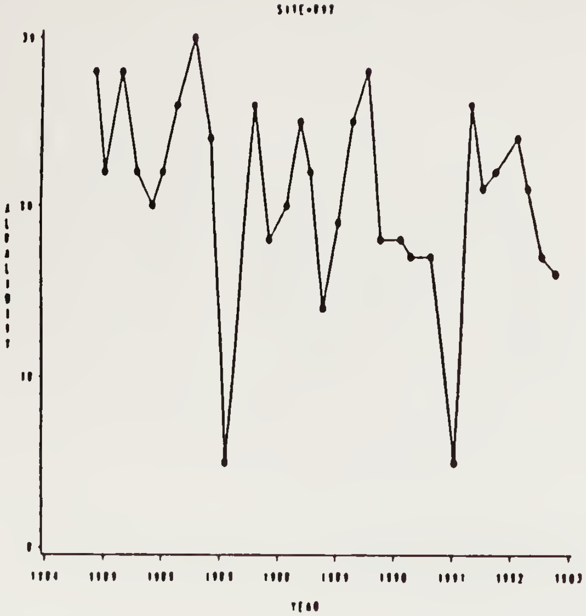

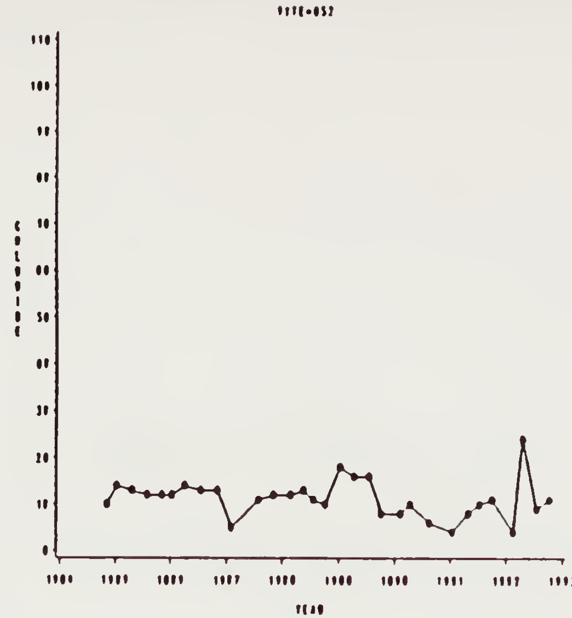

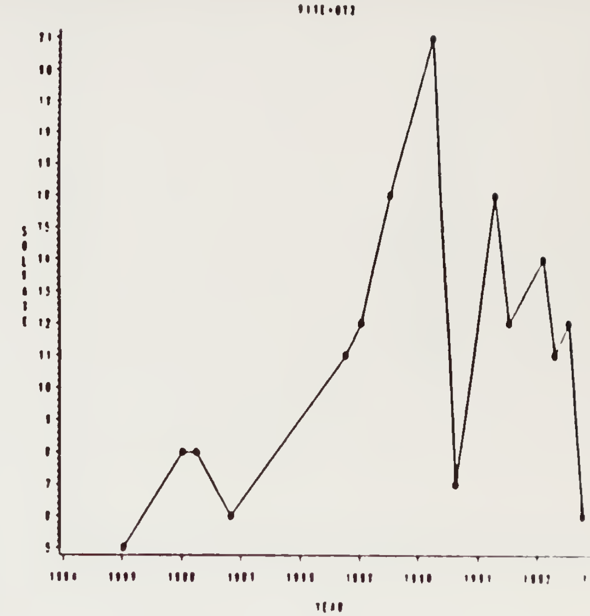


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TOTAL SUSP SOLIDS
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10
20
30
40
50
60
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
YEAR


SITE=BS2
TOTAL DISS SOLIDS
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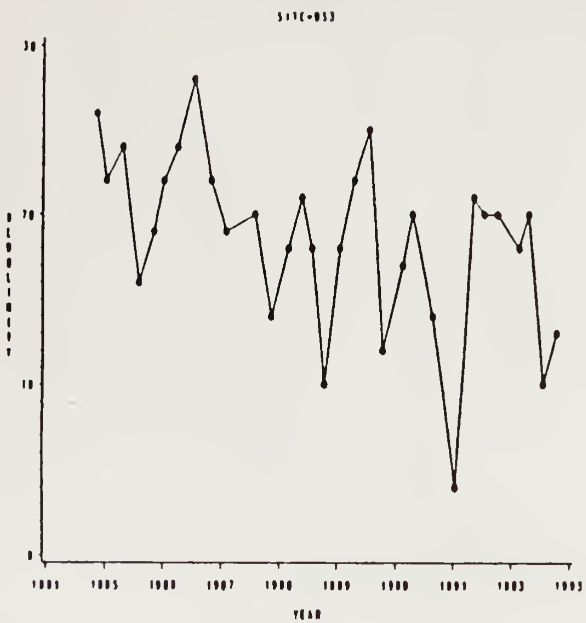
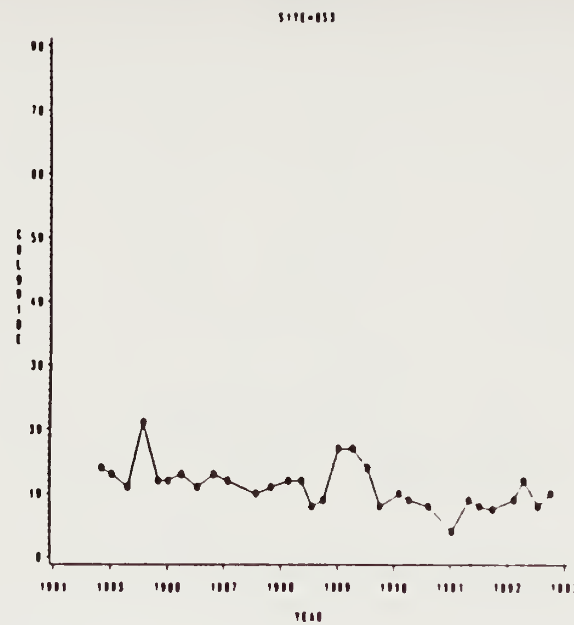
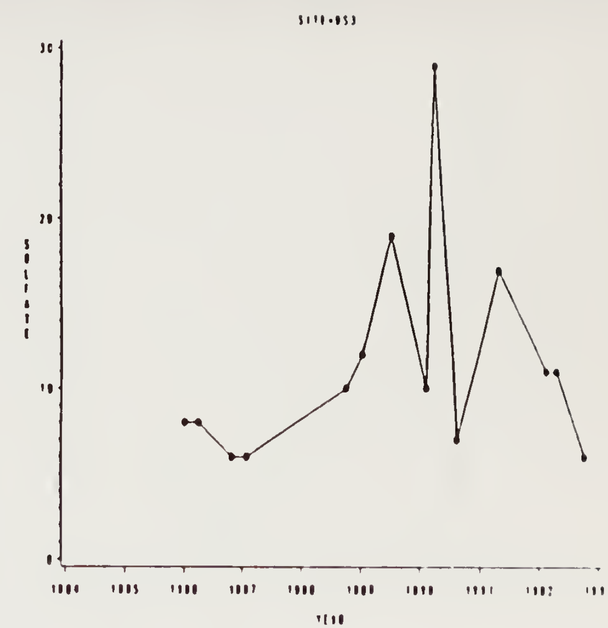
100
200
300
1984
1985
1986
1987
1988
YEAR

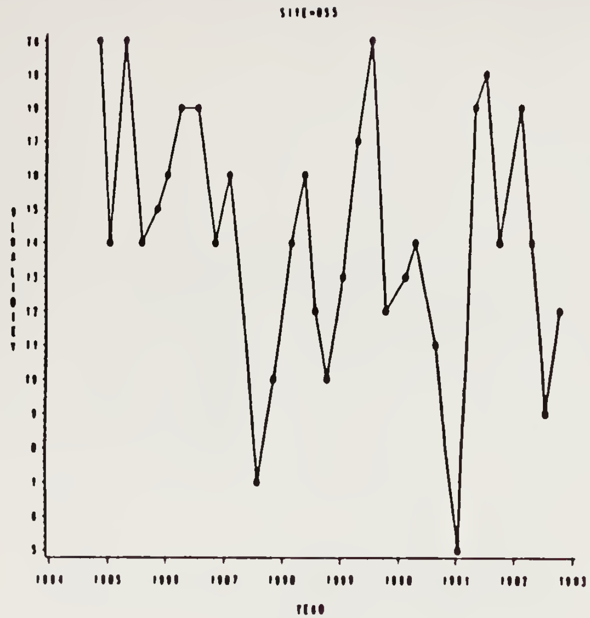


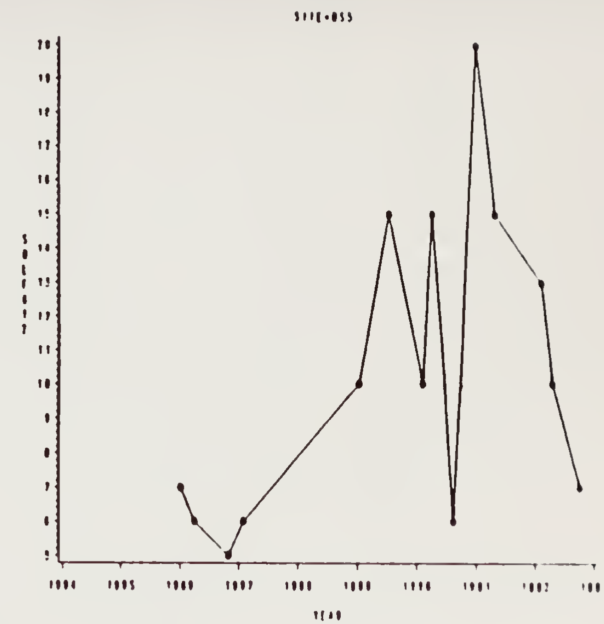





SITE=BS3
TOTAL SUSP SOLIDS
YEAR


SITE=BS3
TOTAL DISS SOLIDS
YEAR



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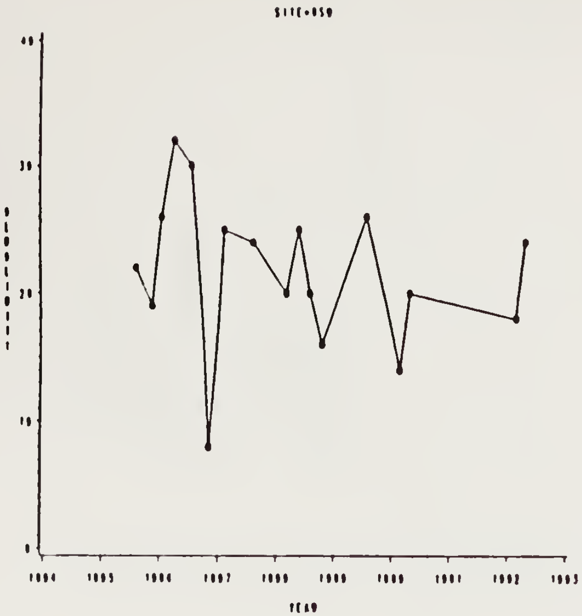
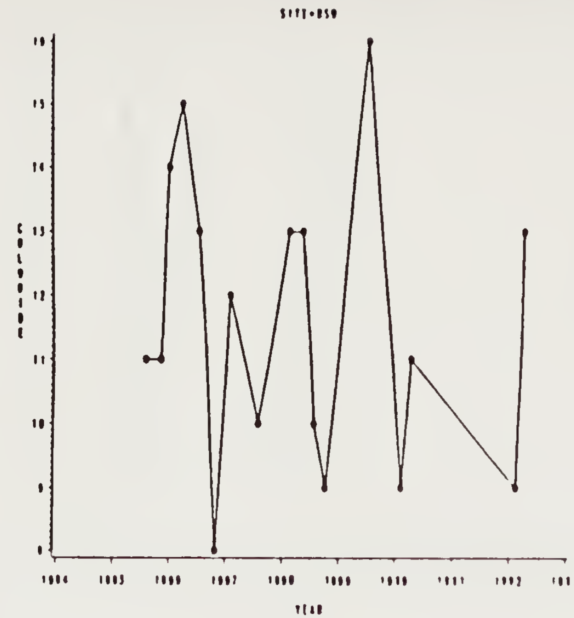
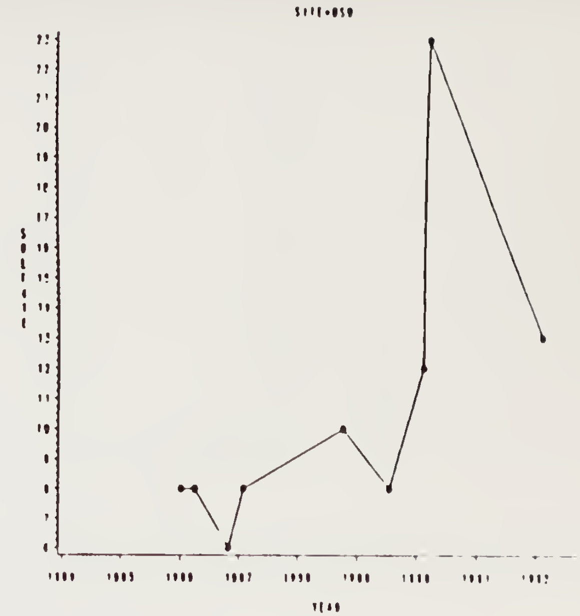
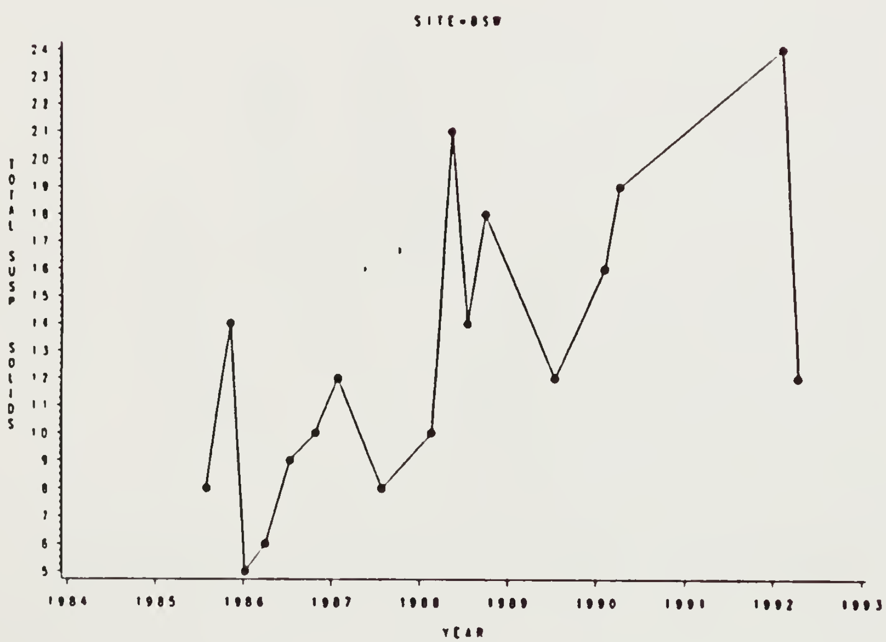
TOTAL SUSP SOLIDS
YEAR


SITE=BSS
TOTAL DISS SOLIDS
YEAR





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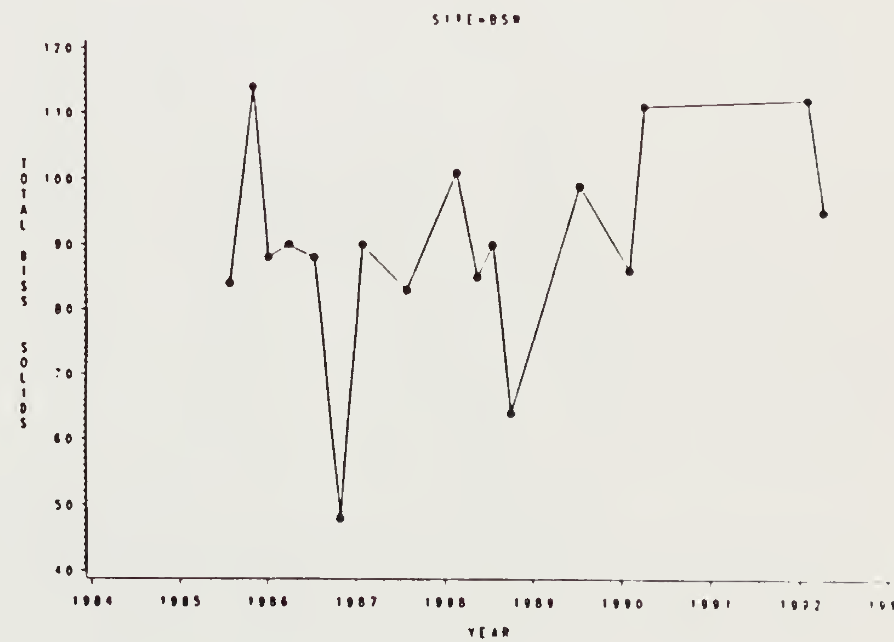
YEAR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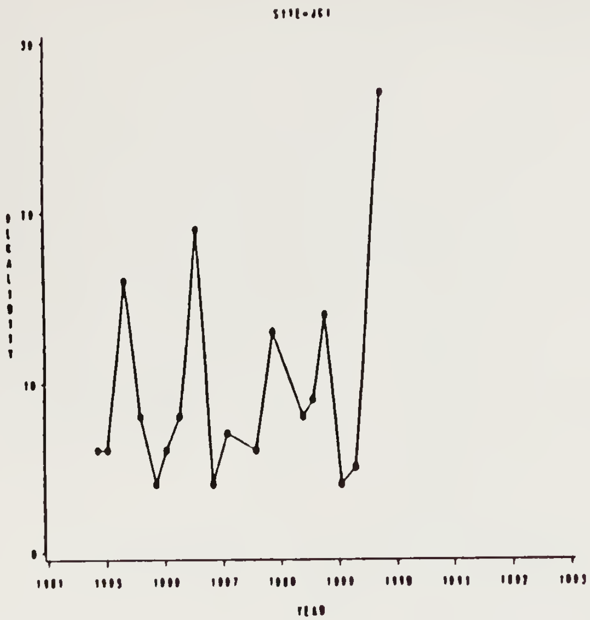
TOTAL DISS SOLIDS
YEAR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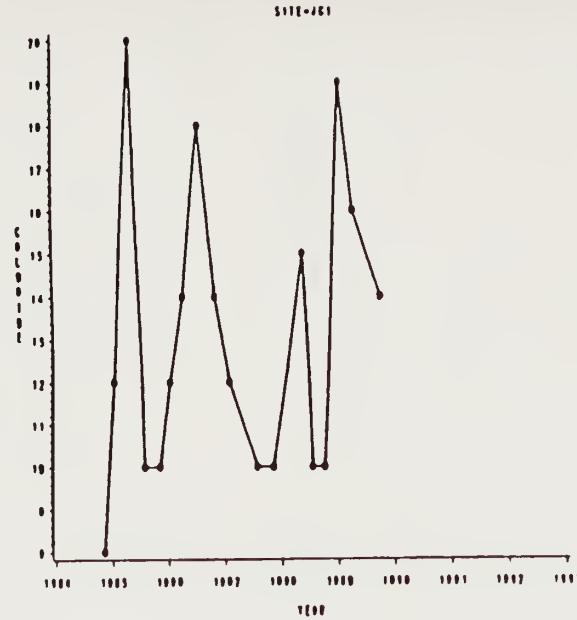
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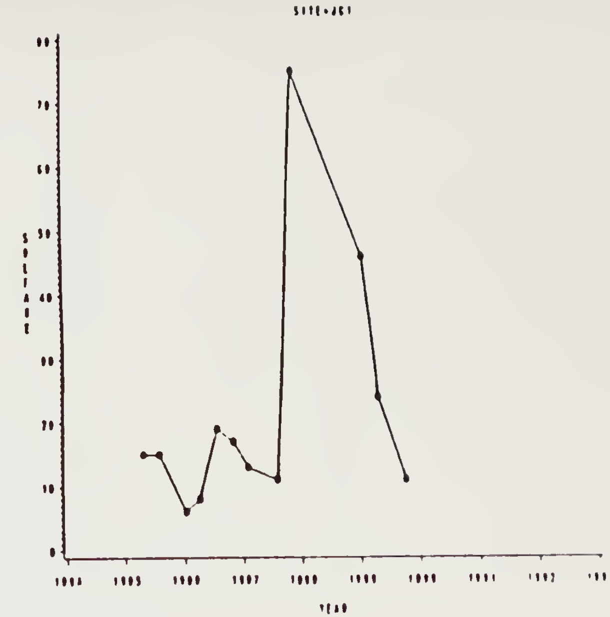
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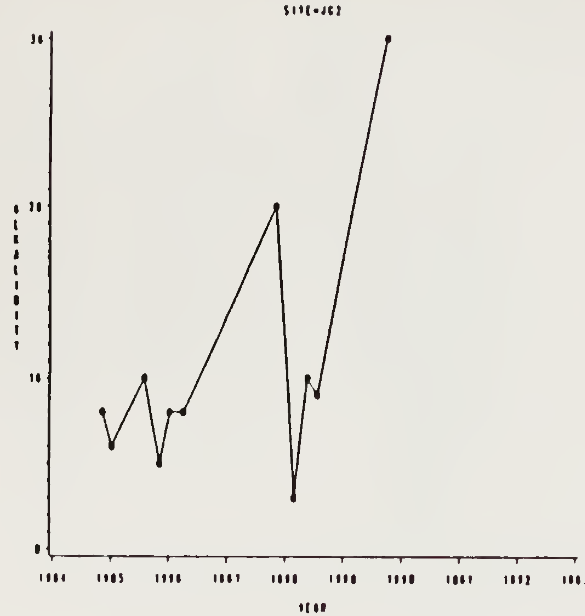
SITE=JC1
TOTAL SUSP SOLIDS
YEAR


SITE=JC1
TOTAL DISS SOLIDS
YEAR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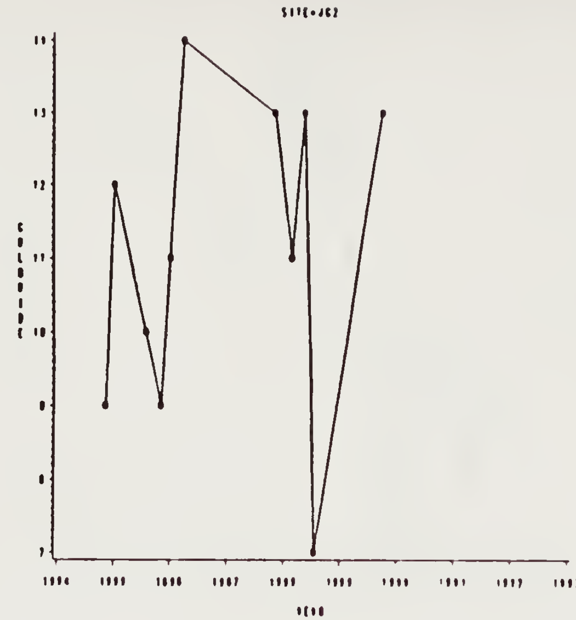
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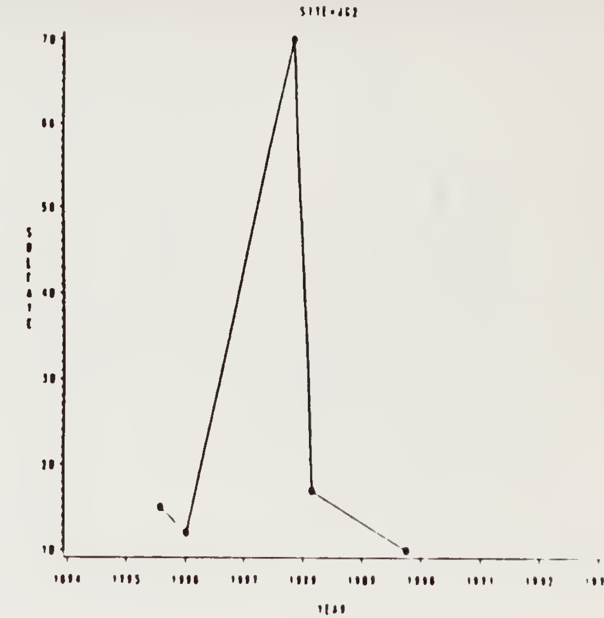
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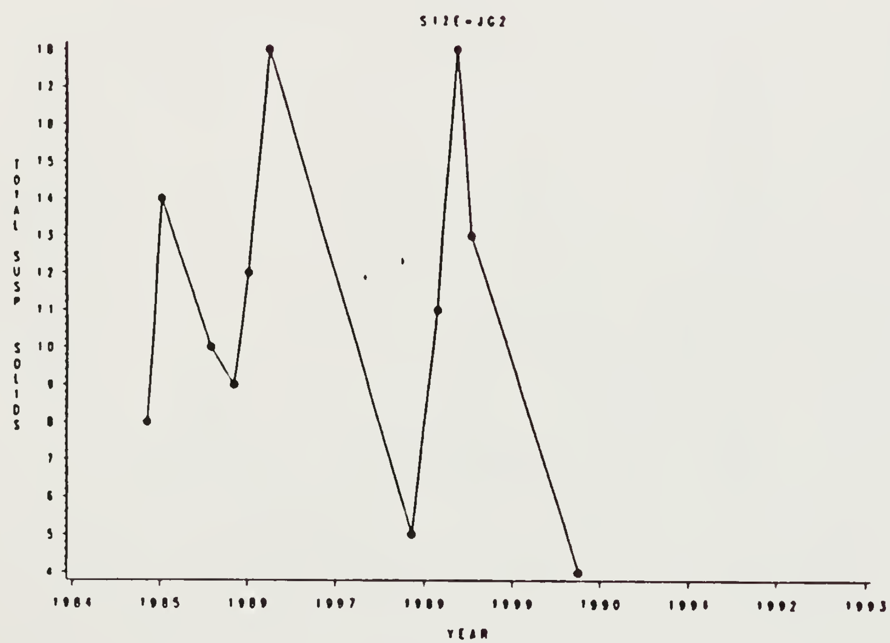
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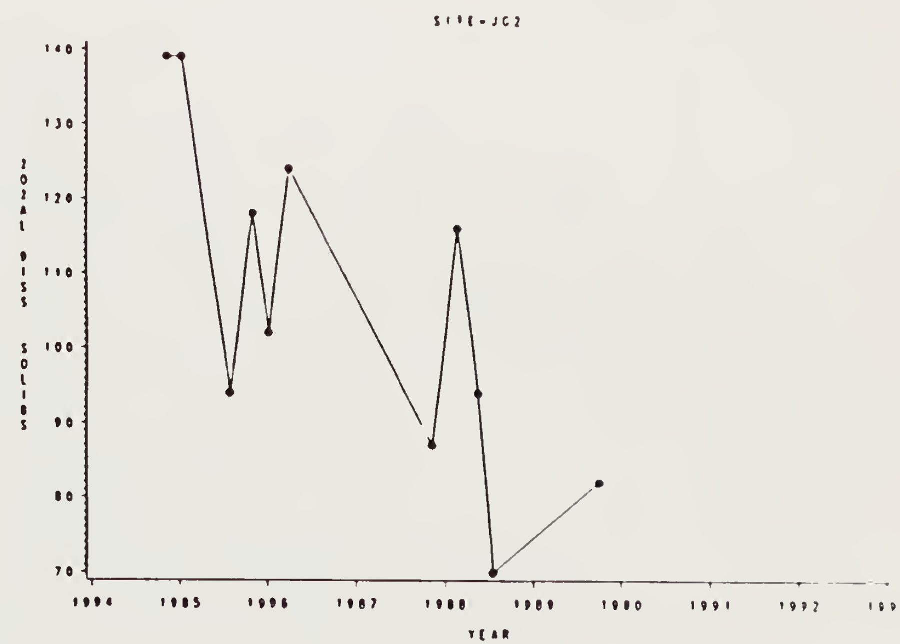
TOTAL SUSP SOLIDS
YEAR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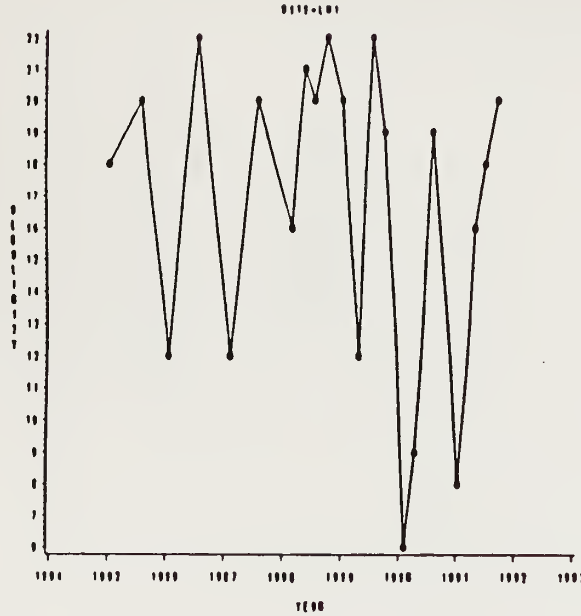
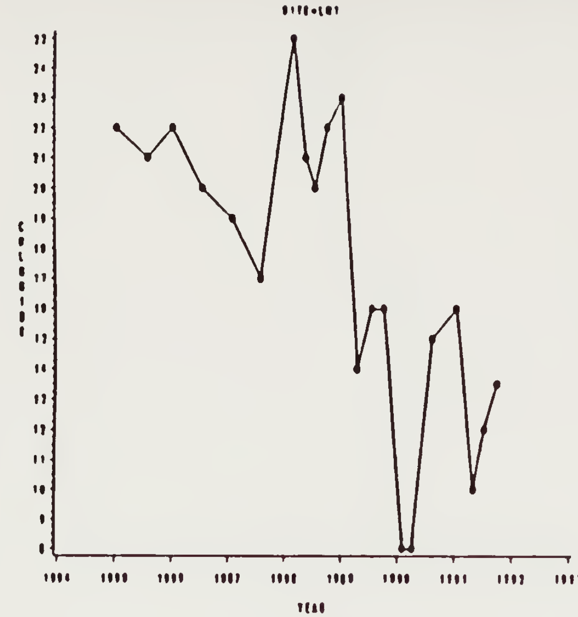
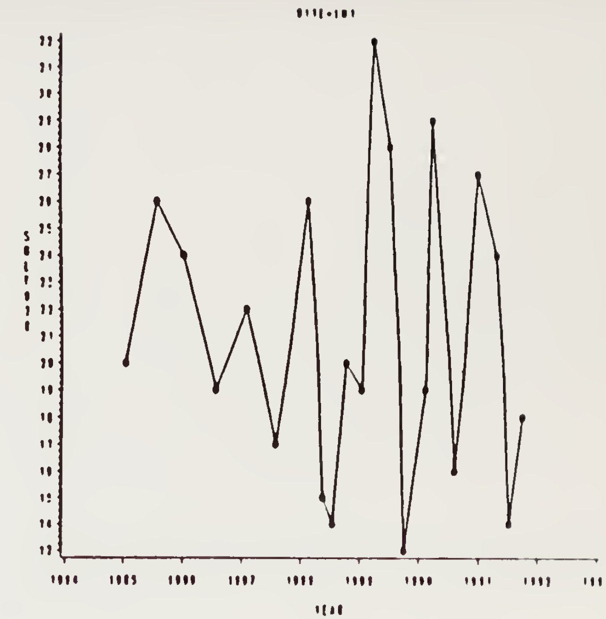
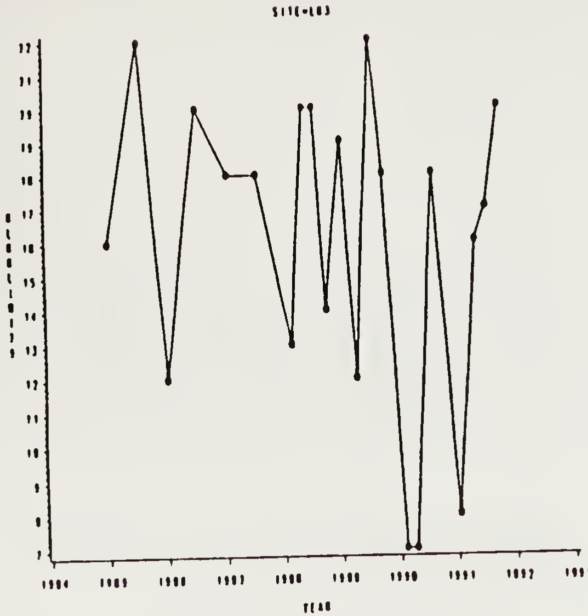


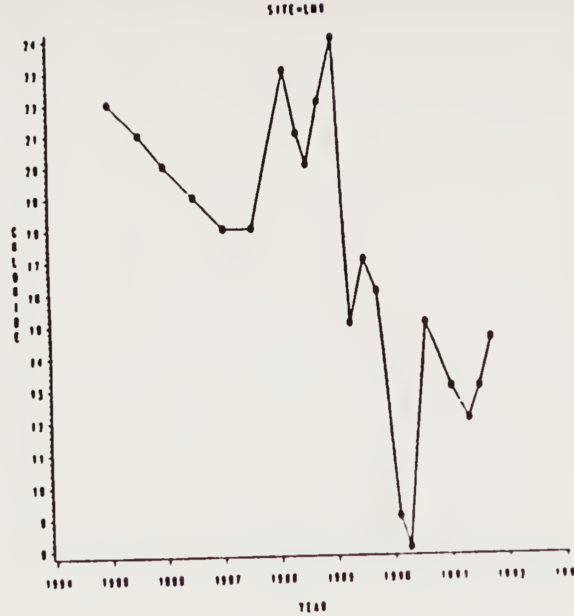


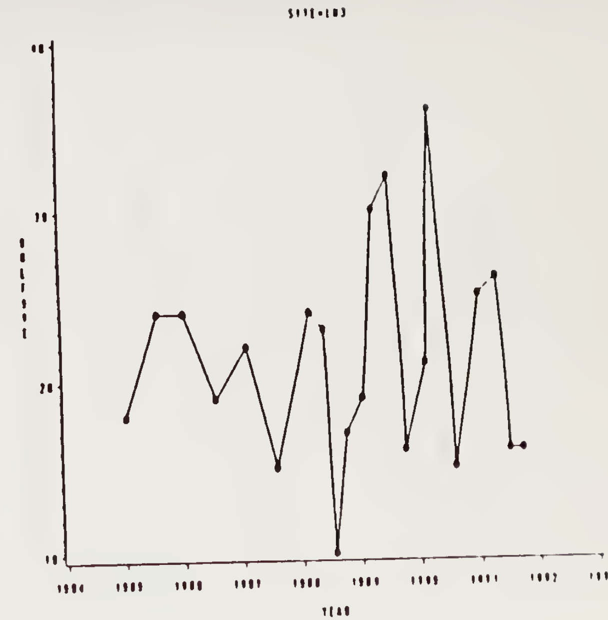


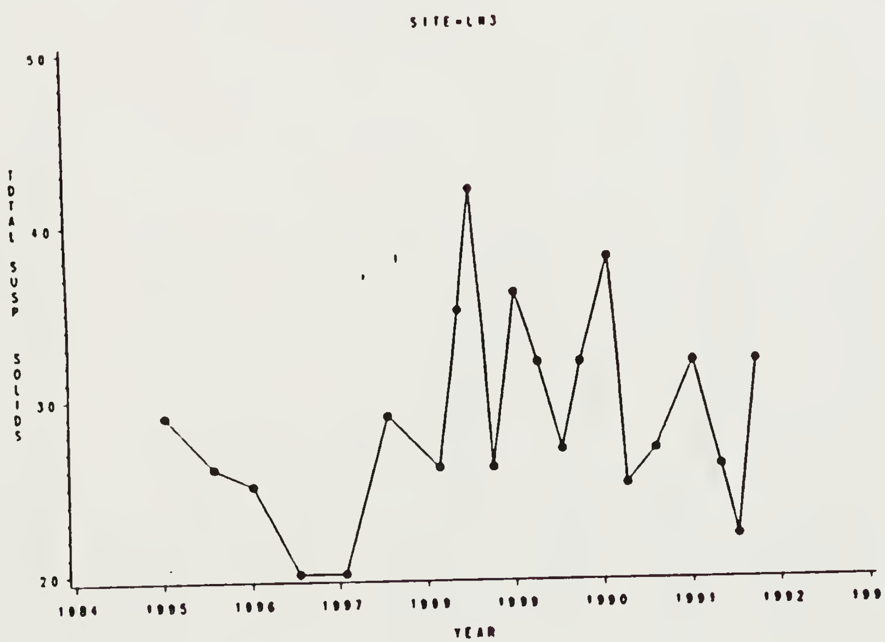

SITE=LN1
TOTAL SUSP SOLIDS
YEAR
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993


SITE=LN1
TOTAL DISS SOLIDS
YEAR








SITE=LH3
TOTAL SUSP SOLIDS
50
40
30
20
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
YEAR


SITE=LH3
TOTAL DISS SOLIDS
170
160
150
140
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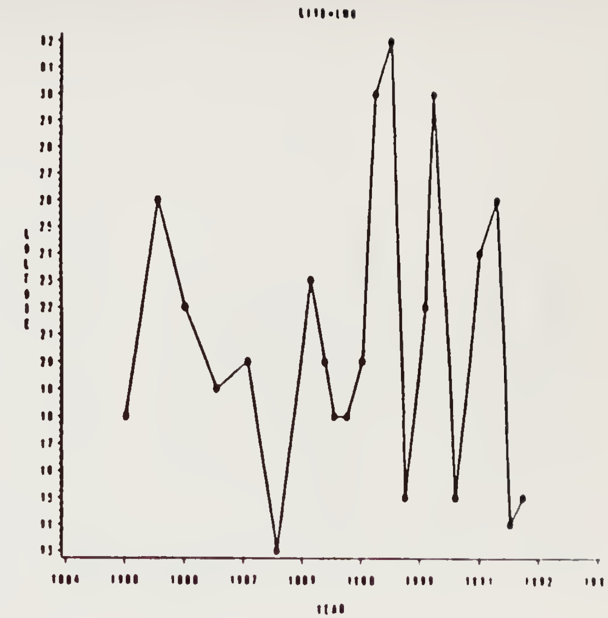
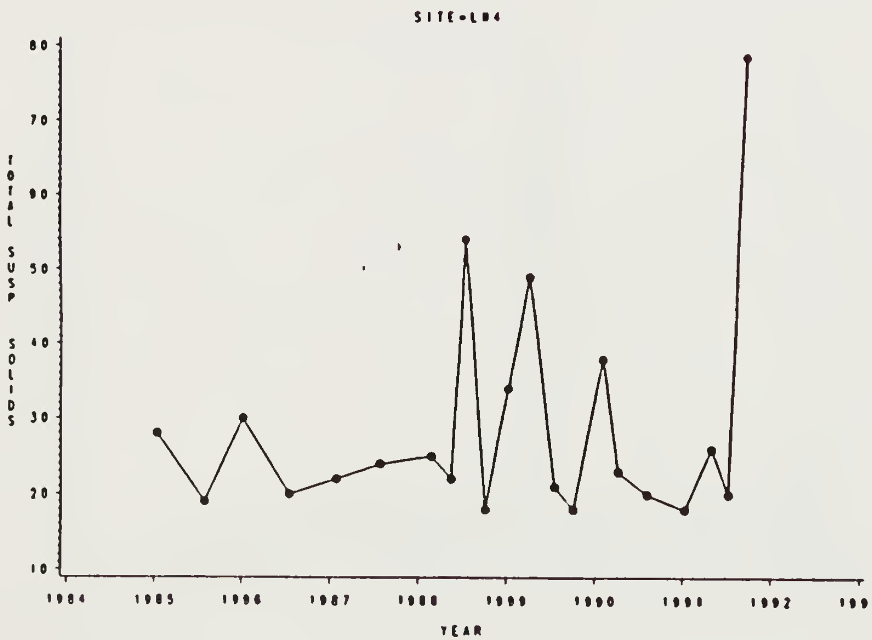
120
110
100
90
80
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
YEAR

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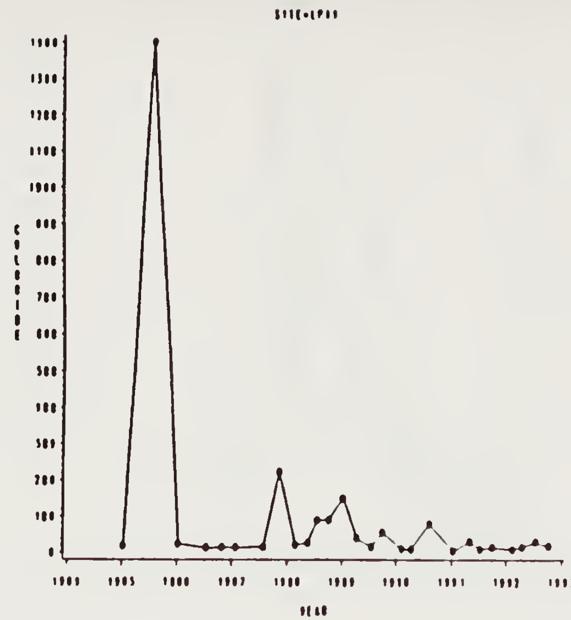
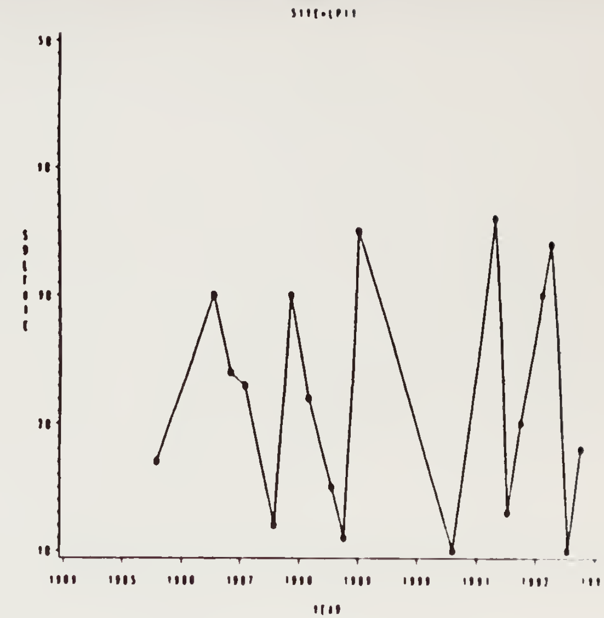
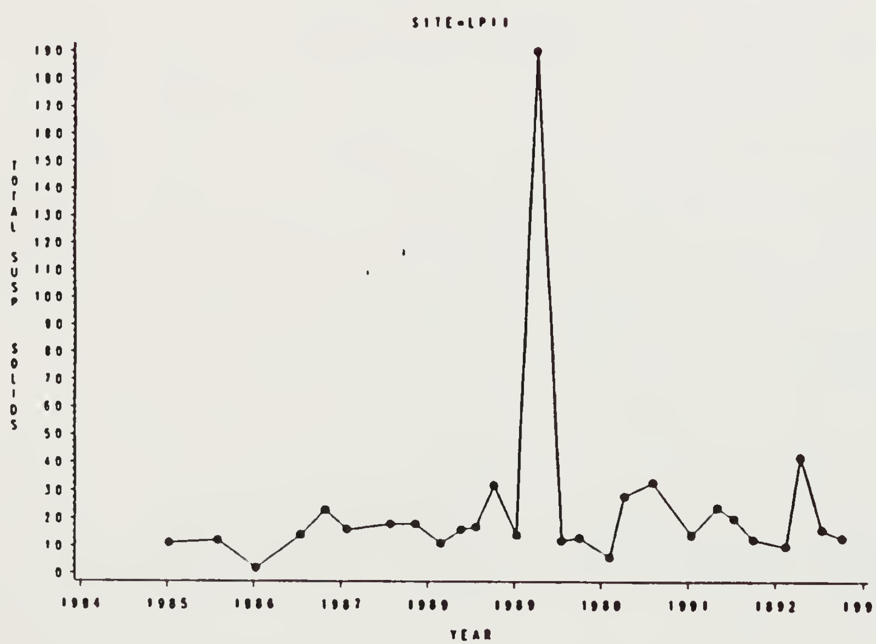
TOTAL SUSP SOLIDS
YEAR


SITE=LN4
TOTAL DISS SOLIDS
YEAR



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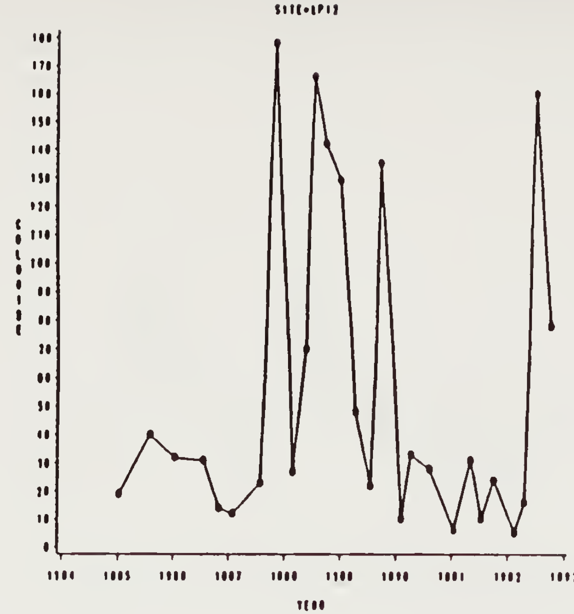
TOTAL SUSP SOLIDS
YEAR


SITE=LP11
TOTAL DISS SOLIDS
YEAR


SITE=LP12
YEAR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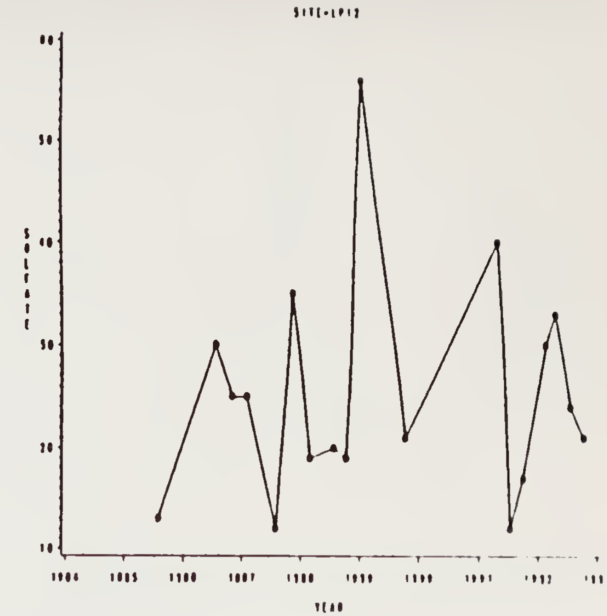
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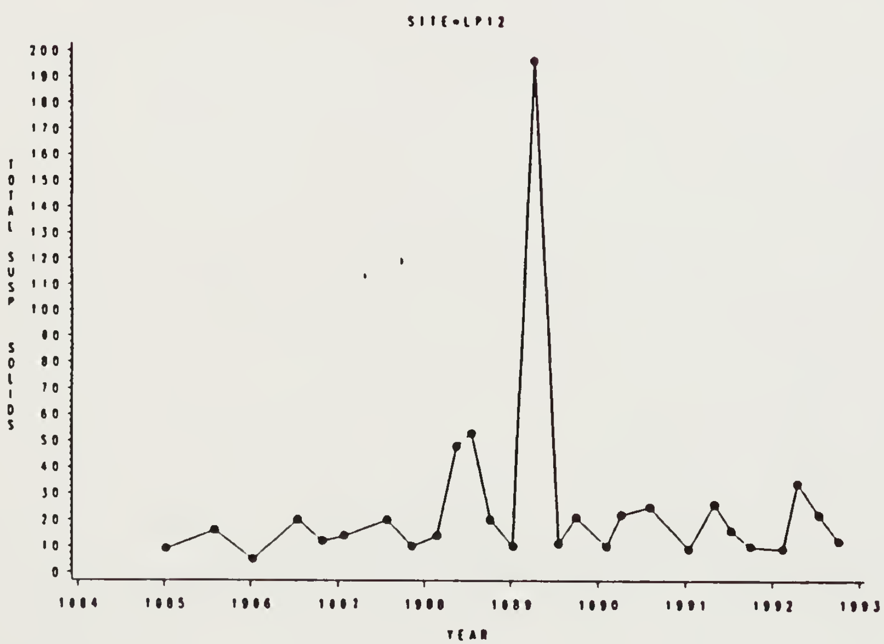
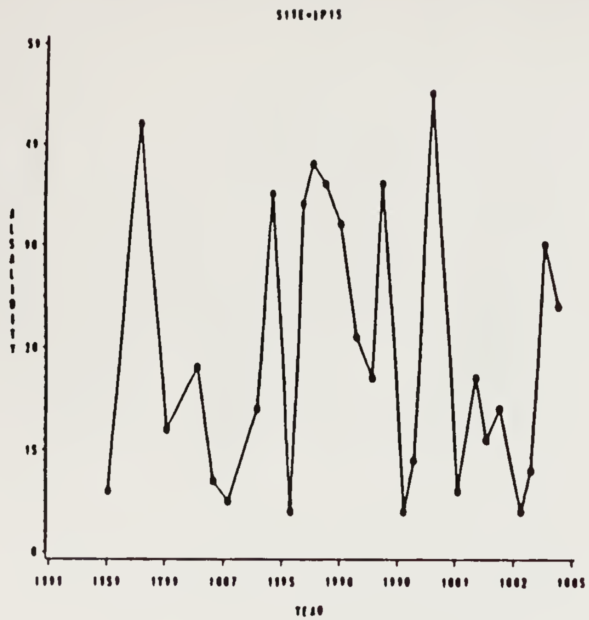
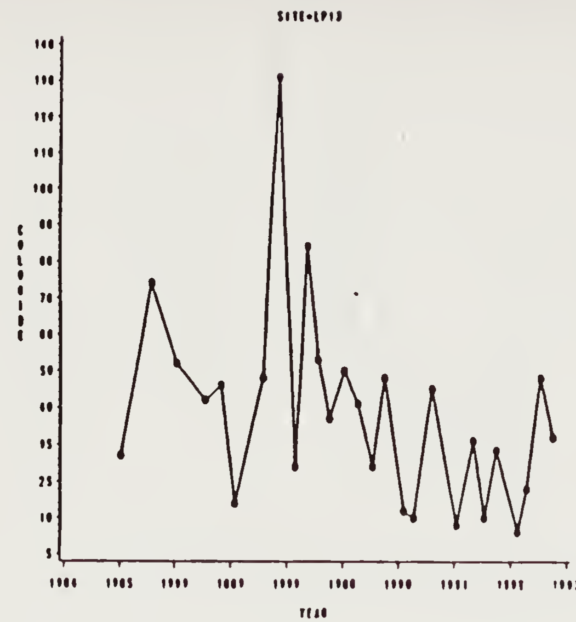
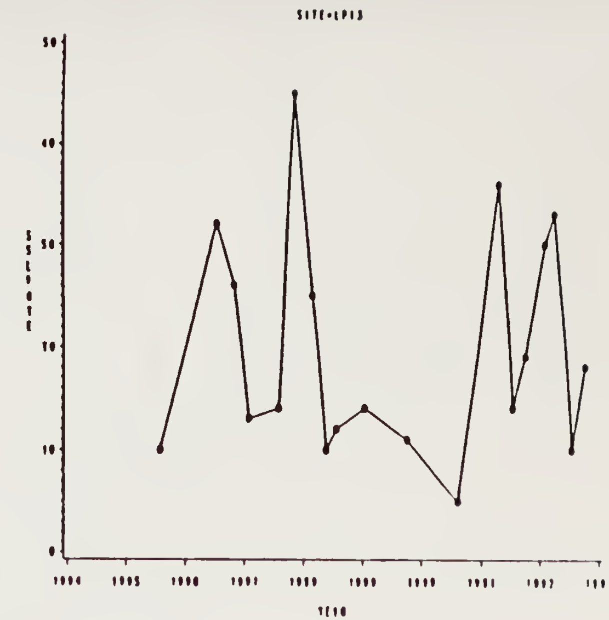
YEAR

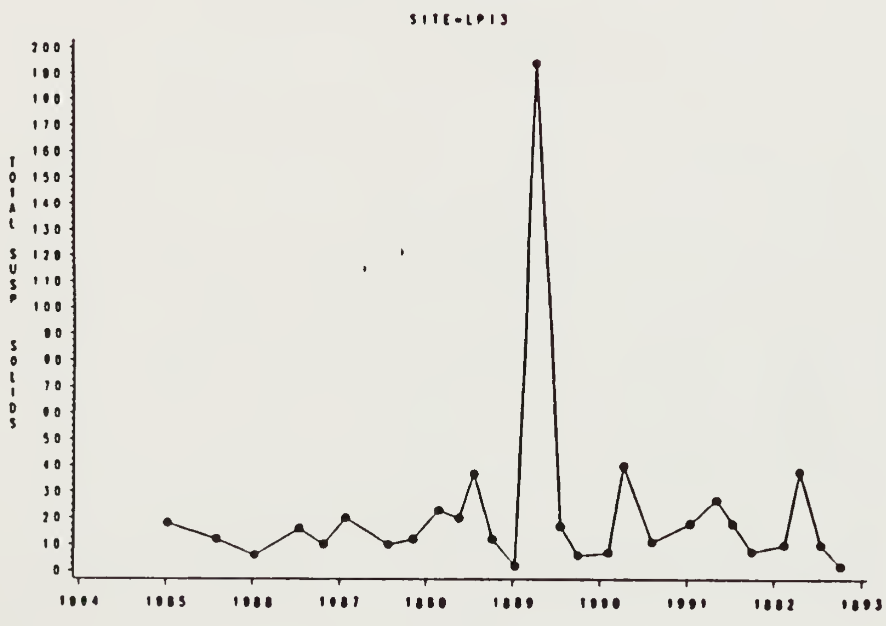

SITE=LP12
TOTAL SUSP SOLIDS
YEAR
1984
1985
1986
1992
1993


SITE=LP12
TOTAL DISS SOLIDS
YEAR
1984
1985
1986
1987
1991









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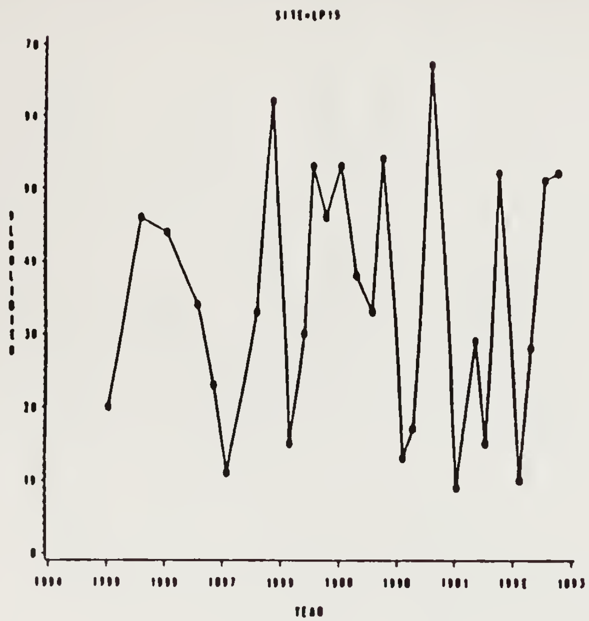
TOTAL SUSP SOLIDS
YEAR

SITE=LP13
TOTAL DISS SOLIDS
YEAR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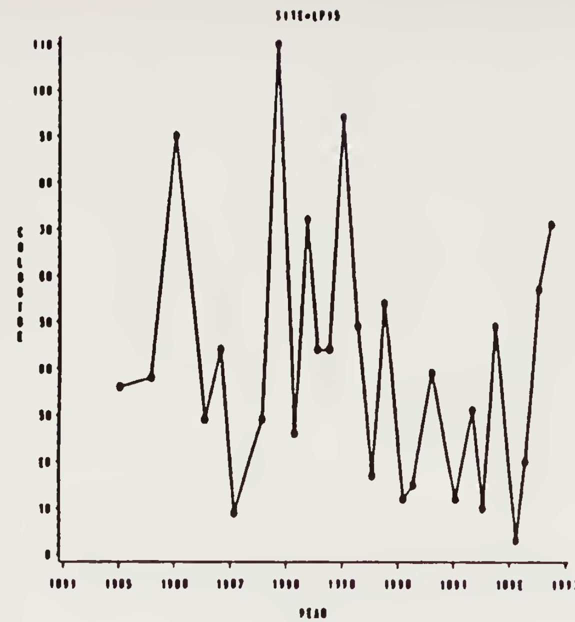
YEAR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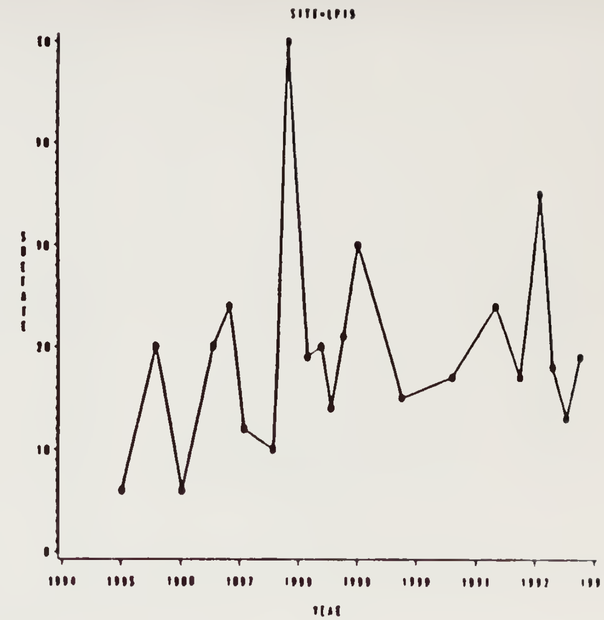
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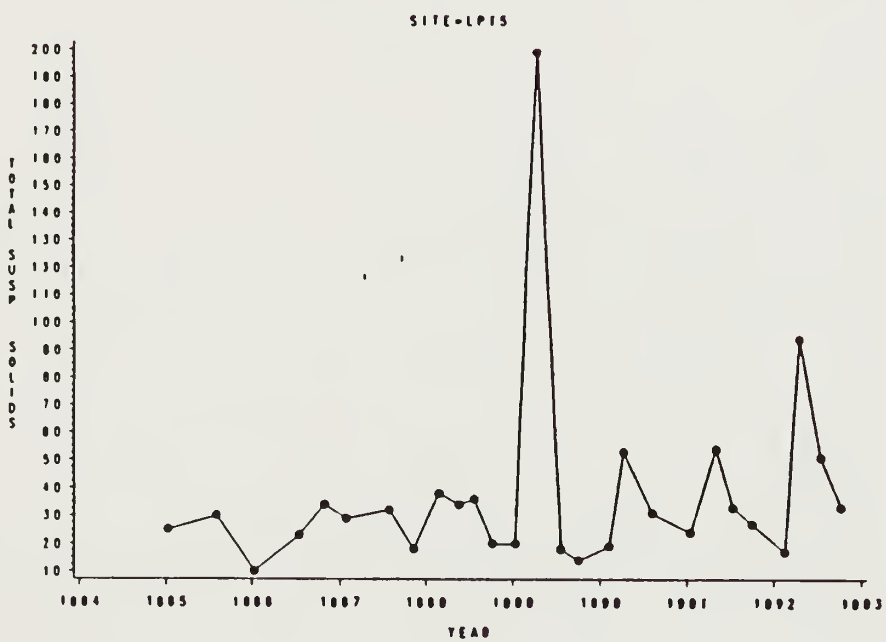
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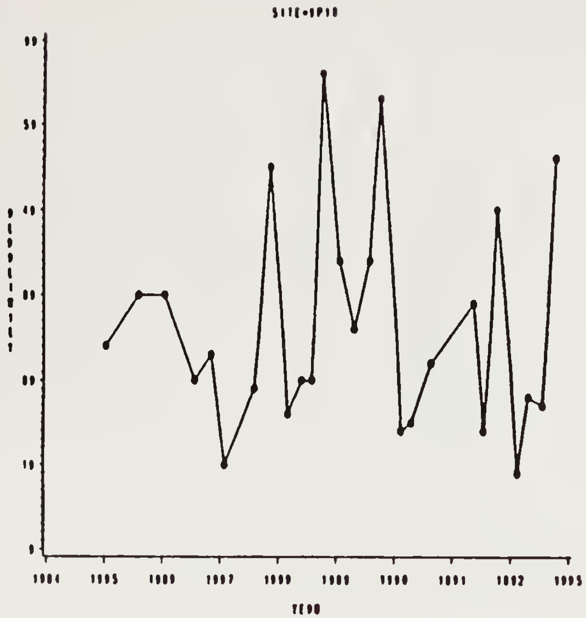
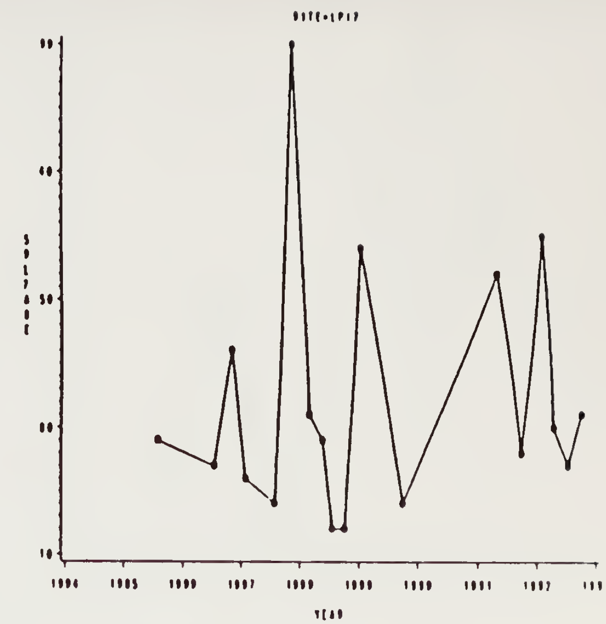
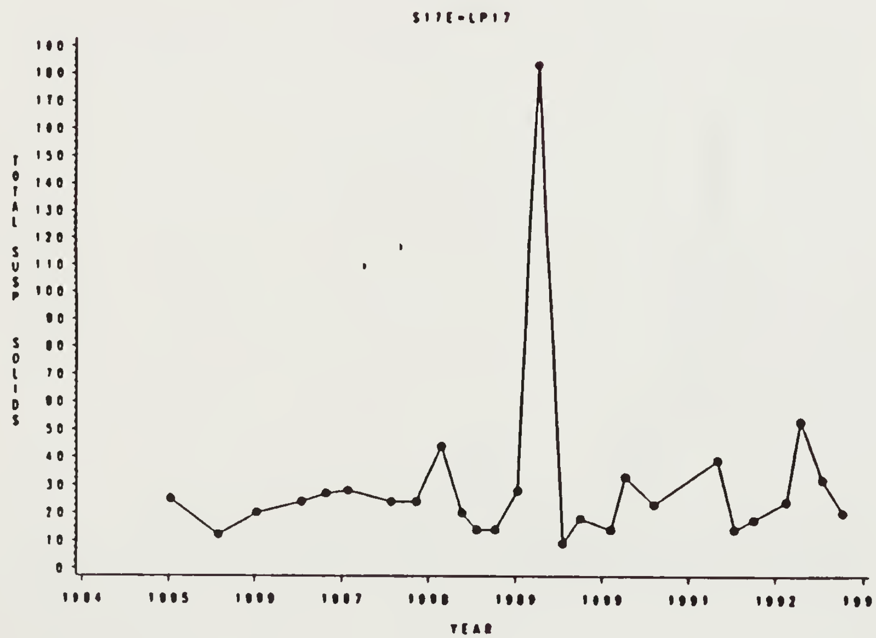
TOTAL SUSP SOLIDS
YEAR


SITE=LPIS
TOTAL DISS SOLIDS
YEAR



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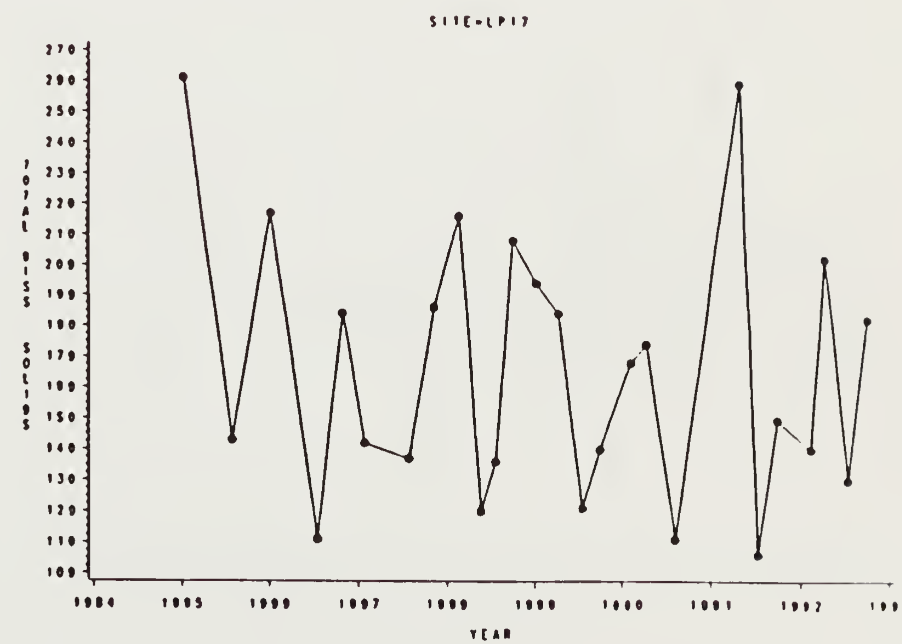
TOTAL SUSP SOLIDS
YEAR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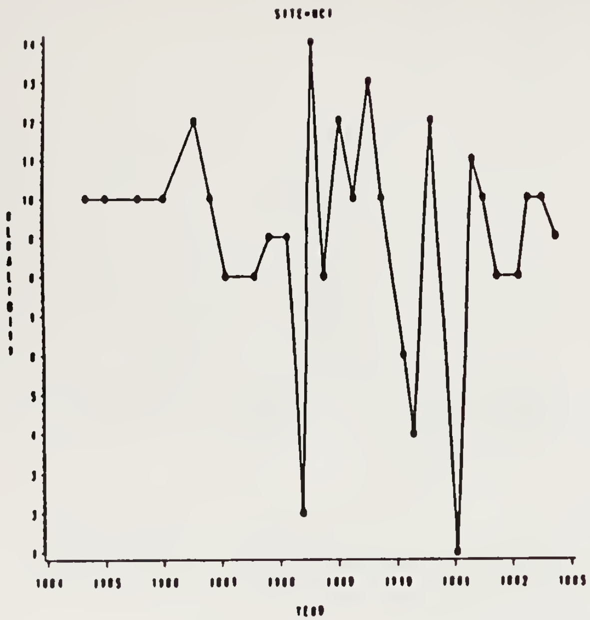
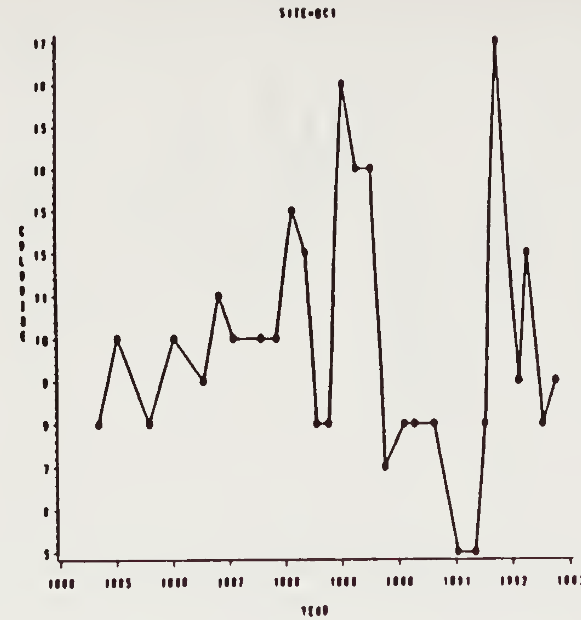
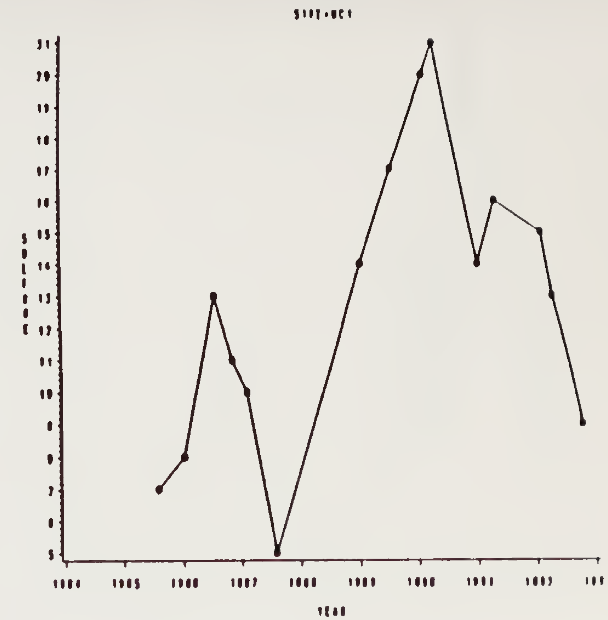
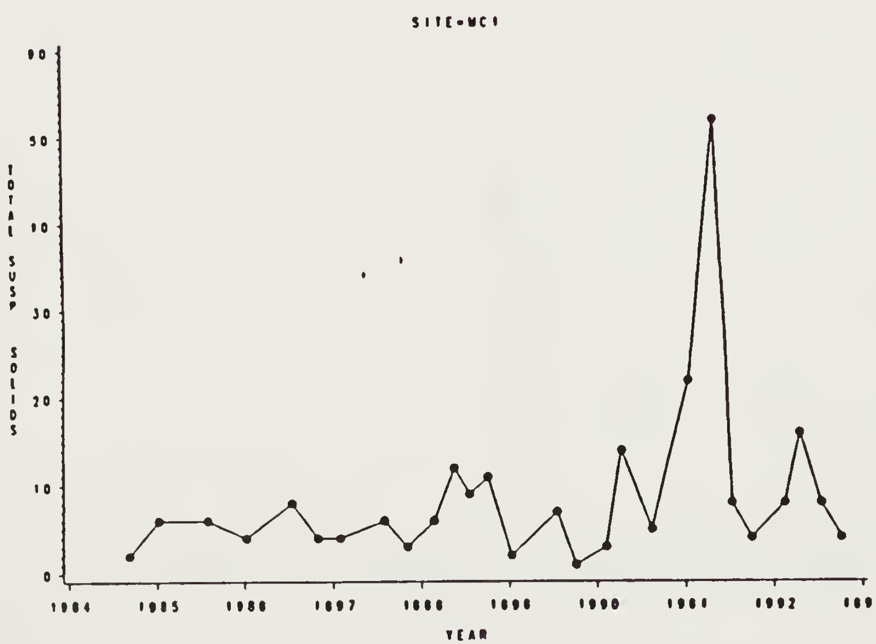
TOTAL DISS SOLIDS
YEAR





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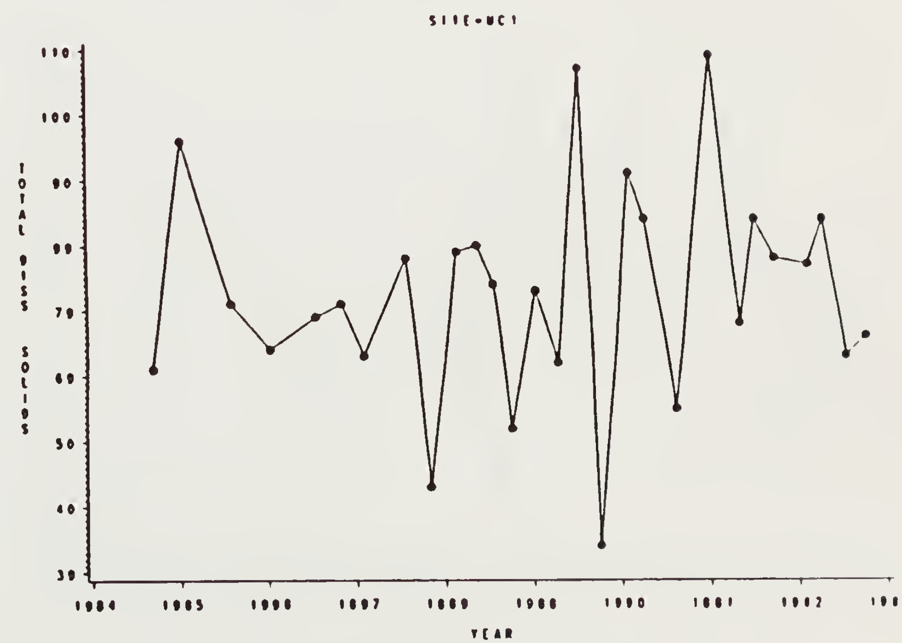
TOTAL SUSP SOLIDS
YEAR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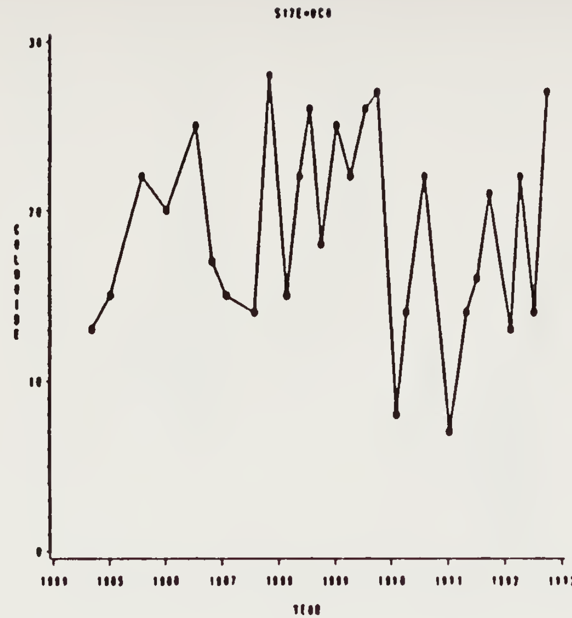
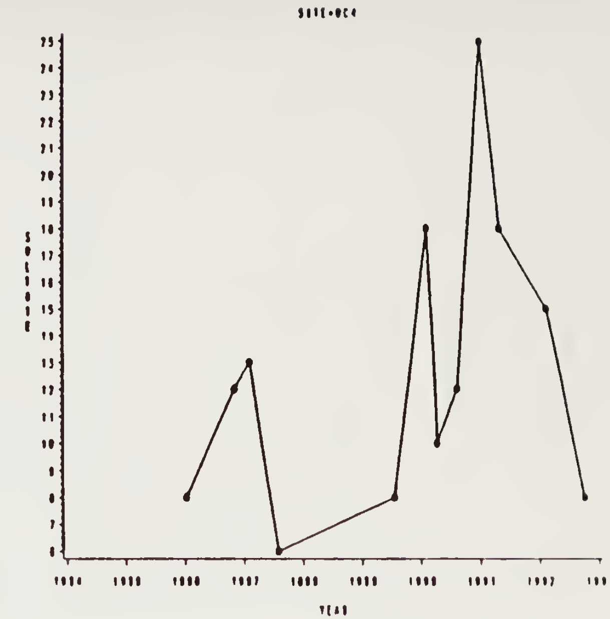
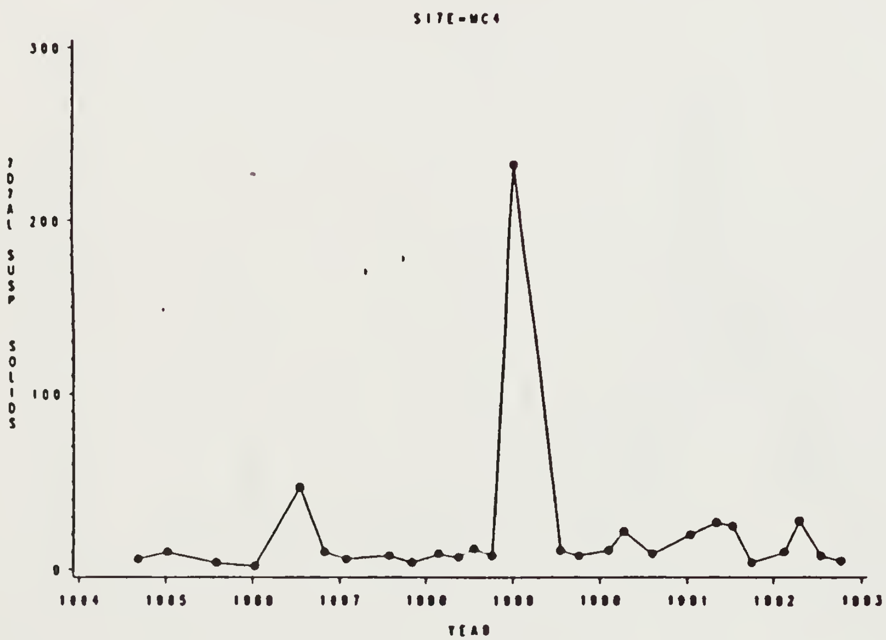
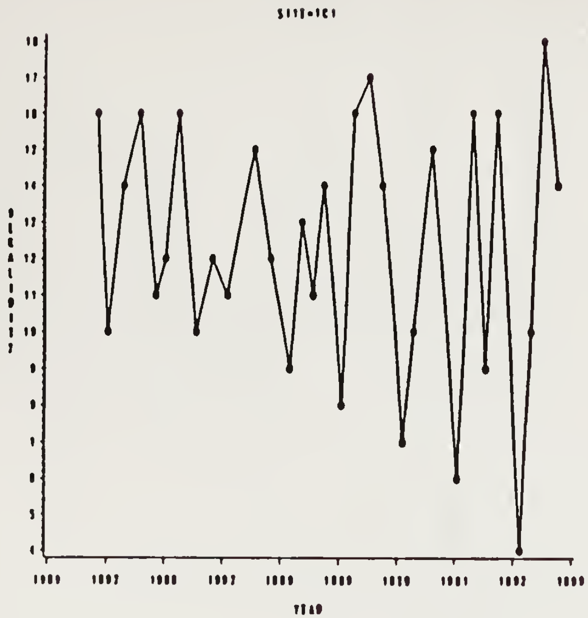
TOTAL DISS SOLIDS
YEAR

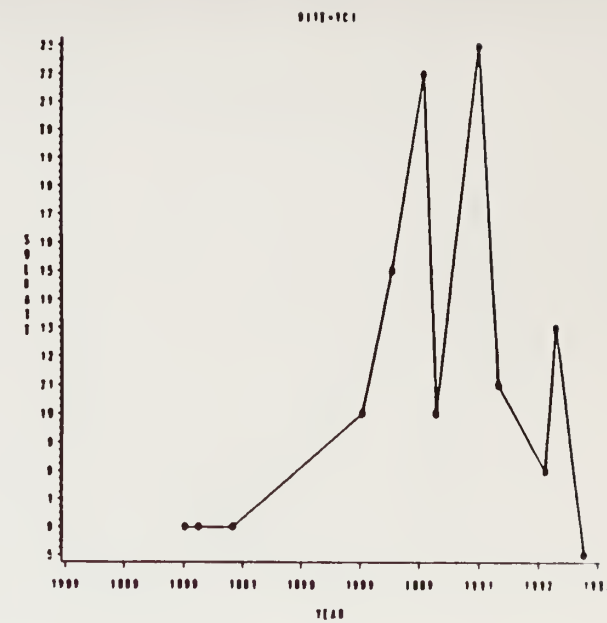





SITE-MC4
TOTAL SUSP SOLIDS
YEAR


SITE-MC4
TOTAL DISS SOLIDS
YEAR



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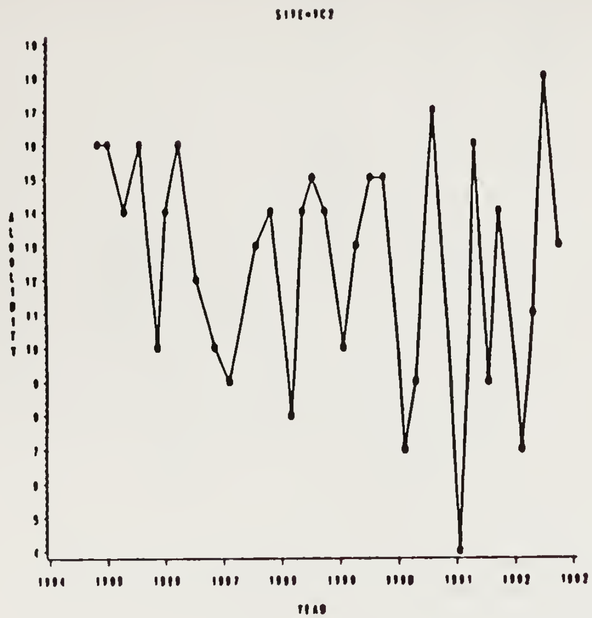
TOTAL SUSP SOLIDS
YEAR


SITE=TC1
TOTAL DISS SOLIDS
YEAR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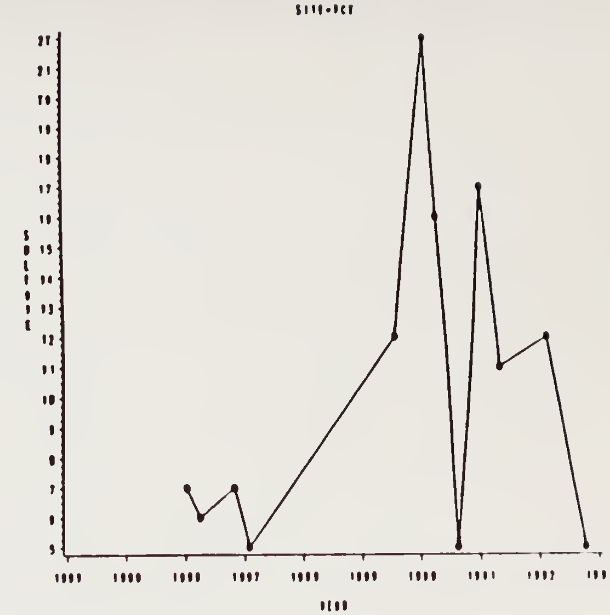
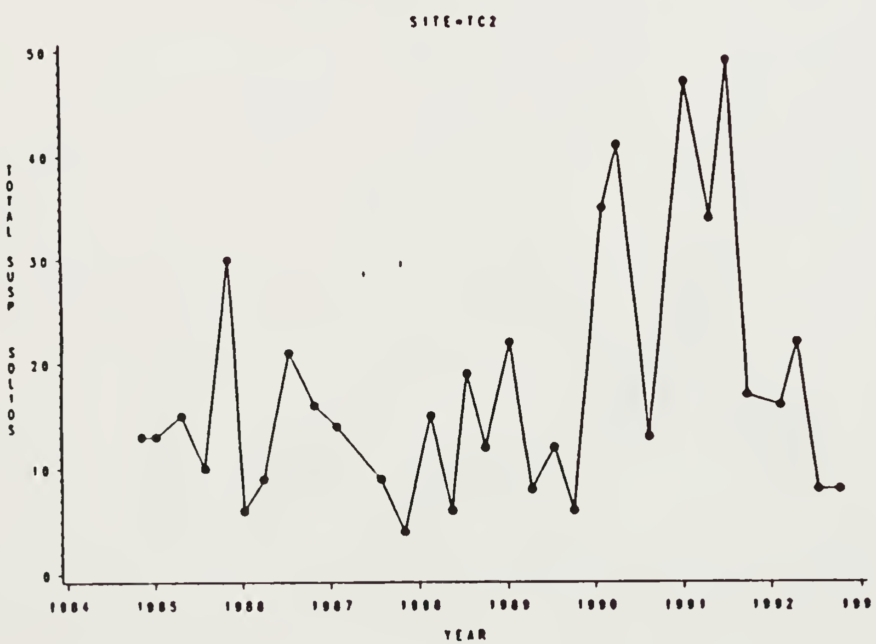
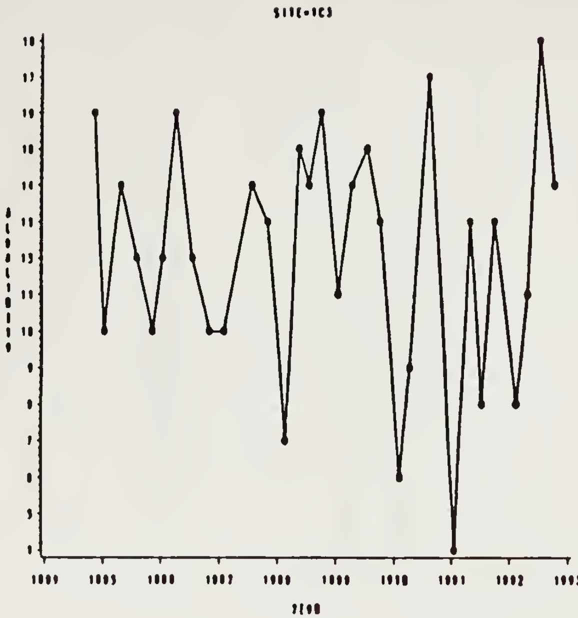
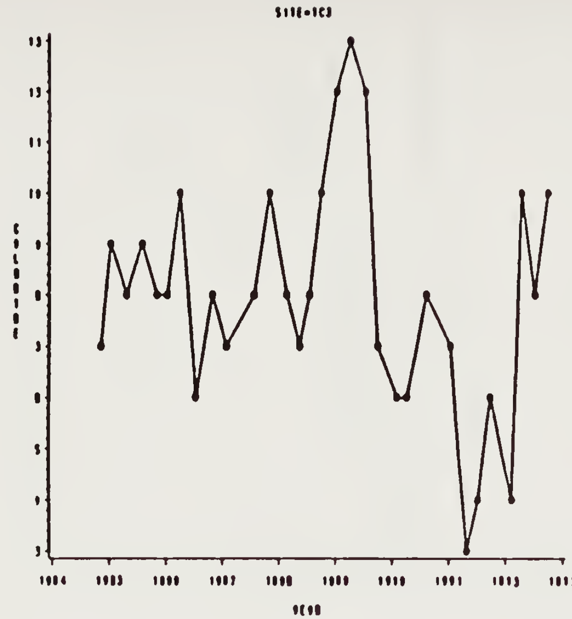
SITE=TC2

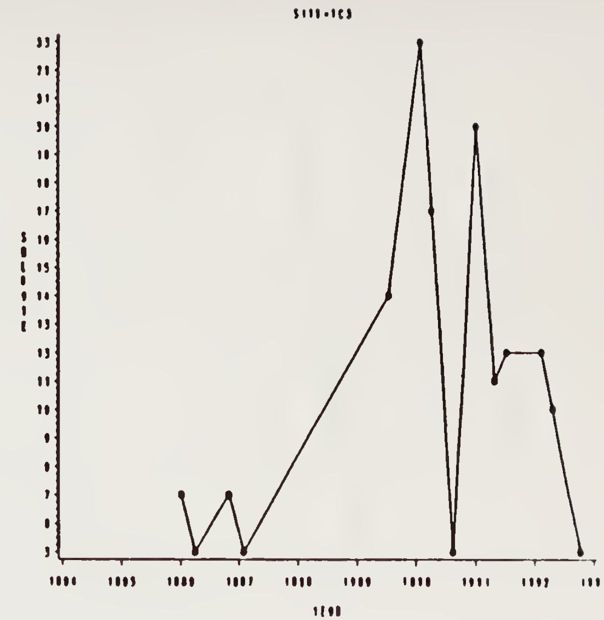


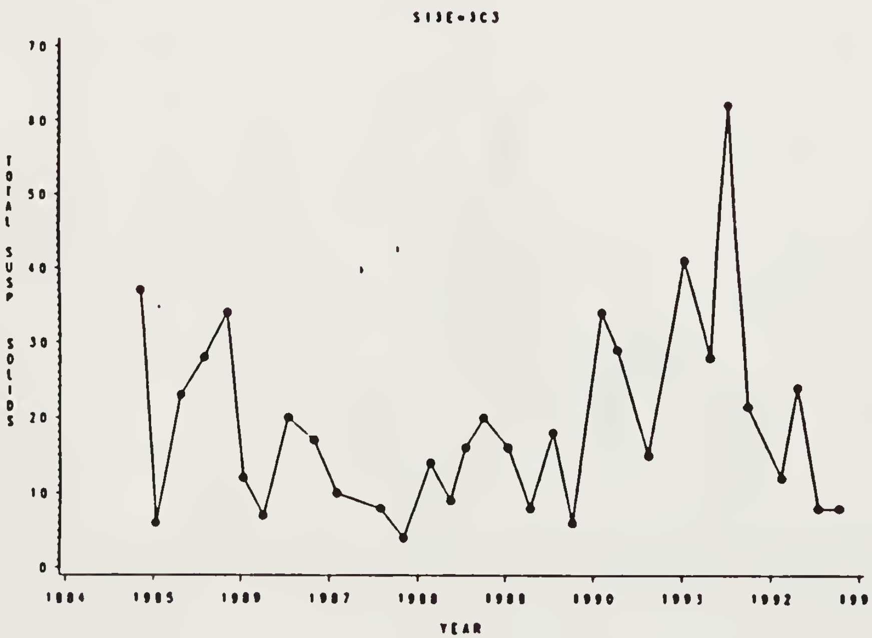

SITE=TC2
TOTAL SUSP SOLIDS
YEAR

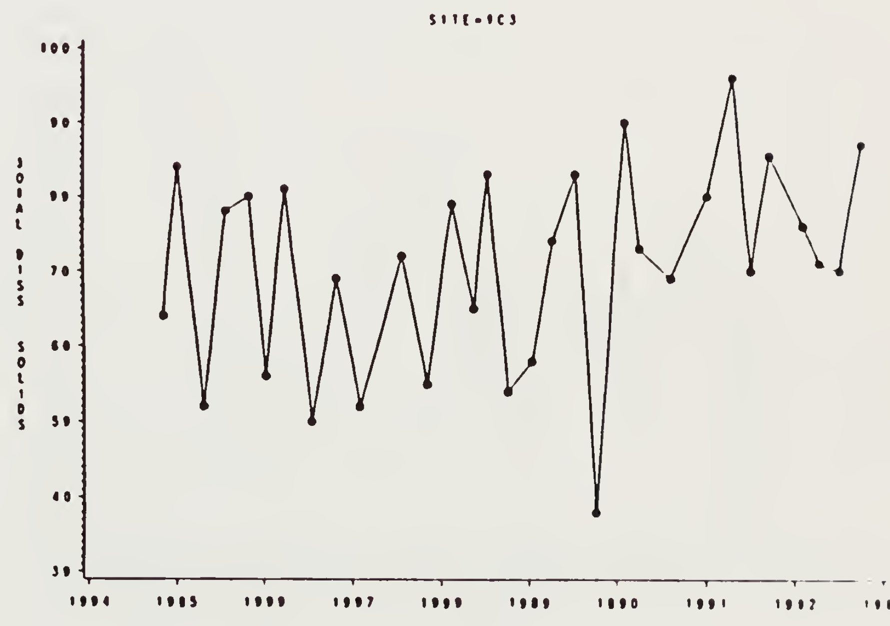

SITE=TC2
TOTAL DISS SOLIDS
YEAR

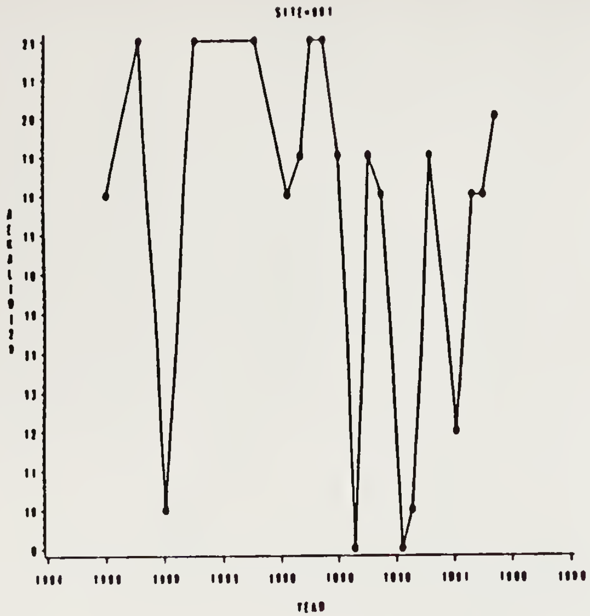


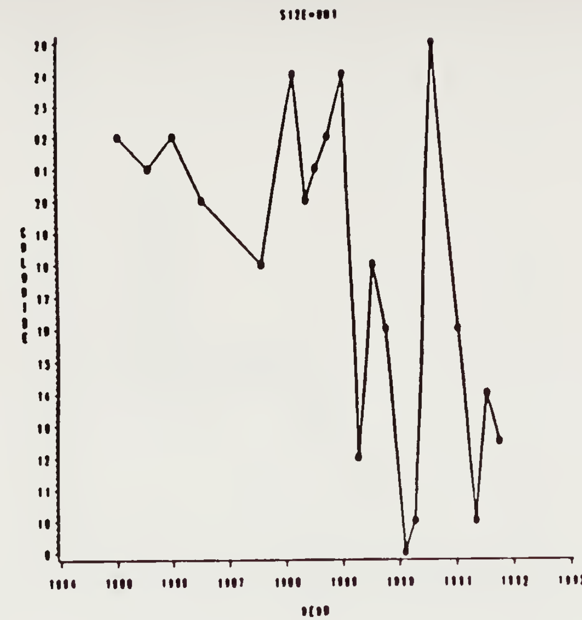


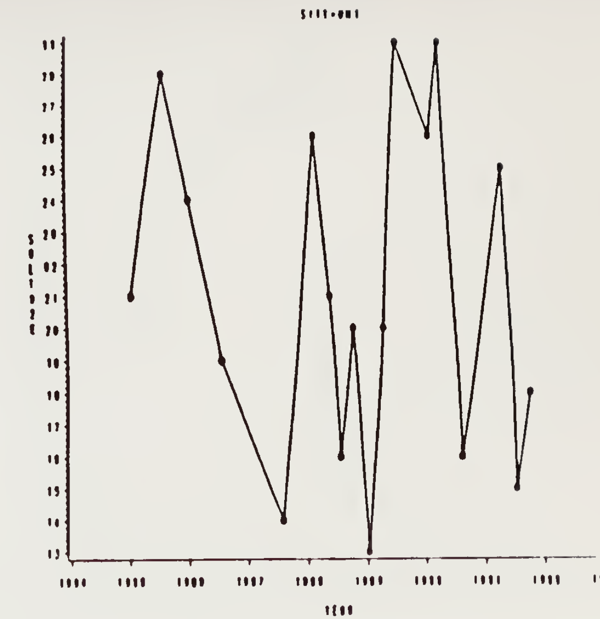


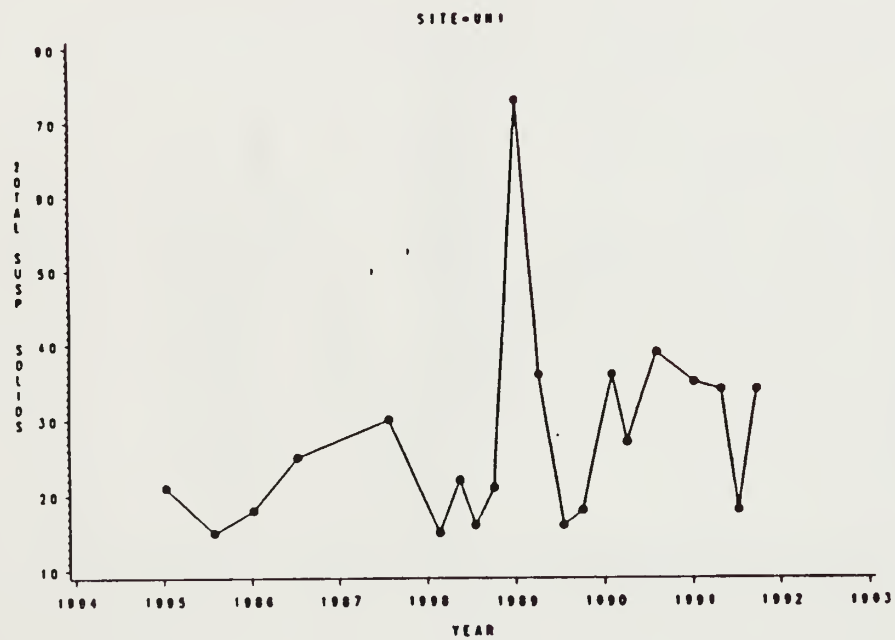

TOTAL SUSP SOLIDS
YEAR


TOTAL DISS SOLIDS
YEAR





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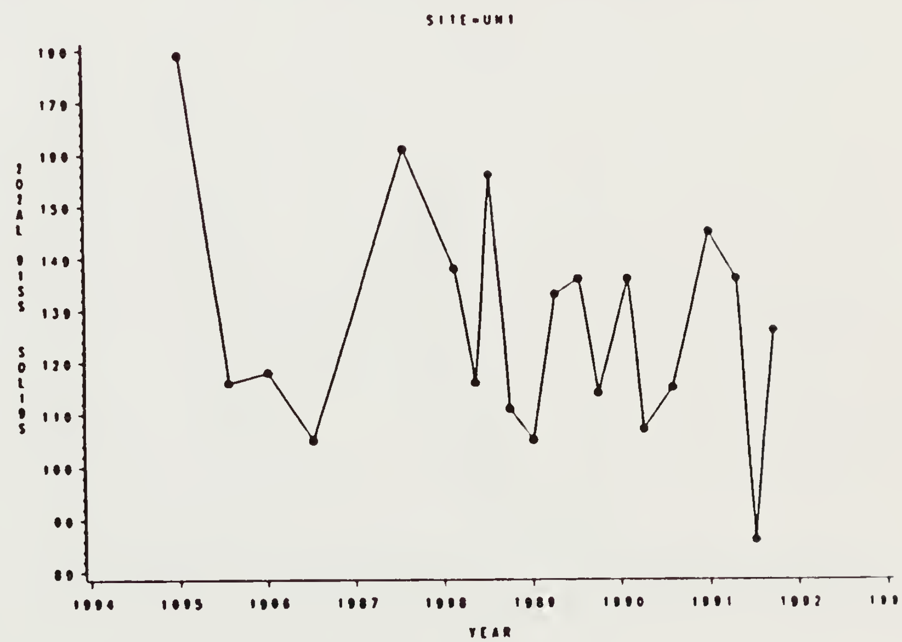
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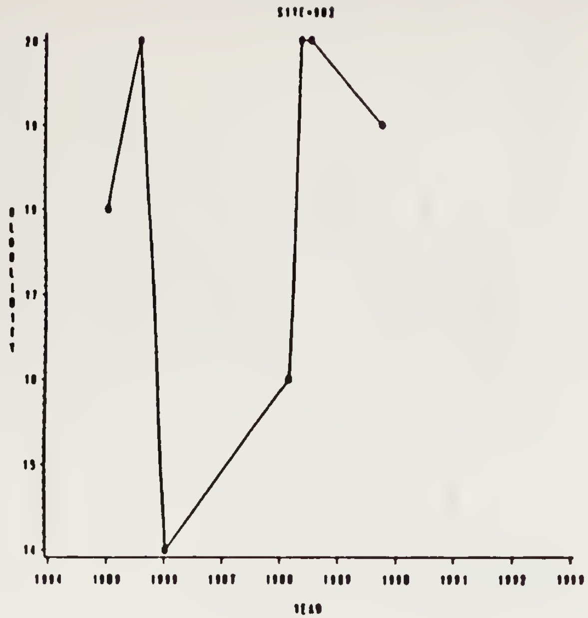

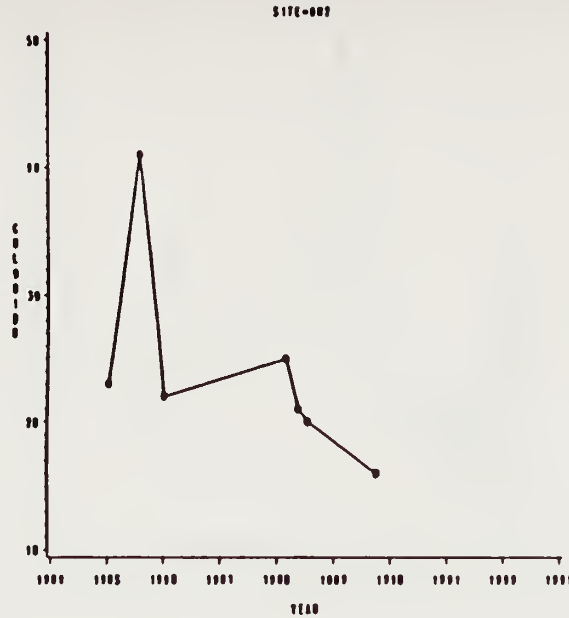

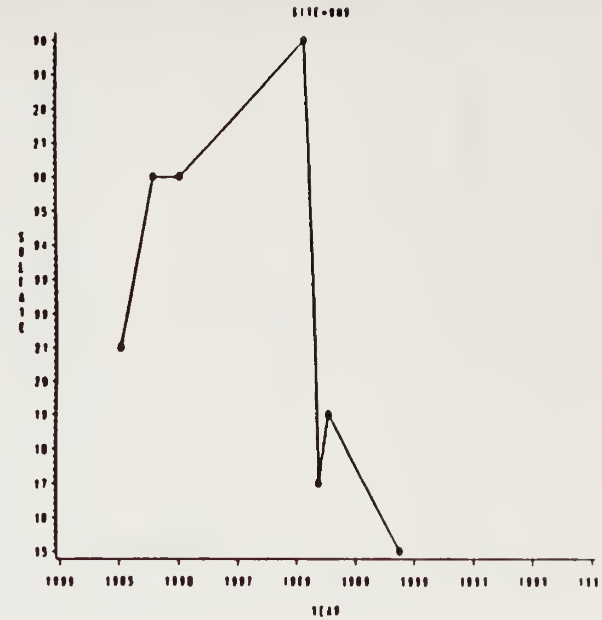

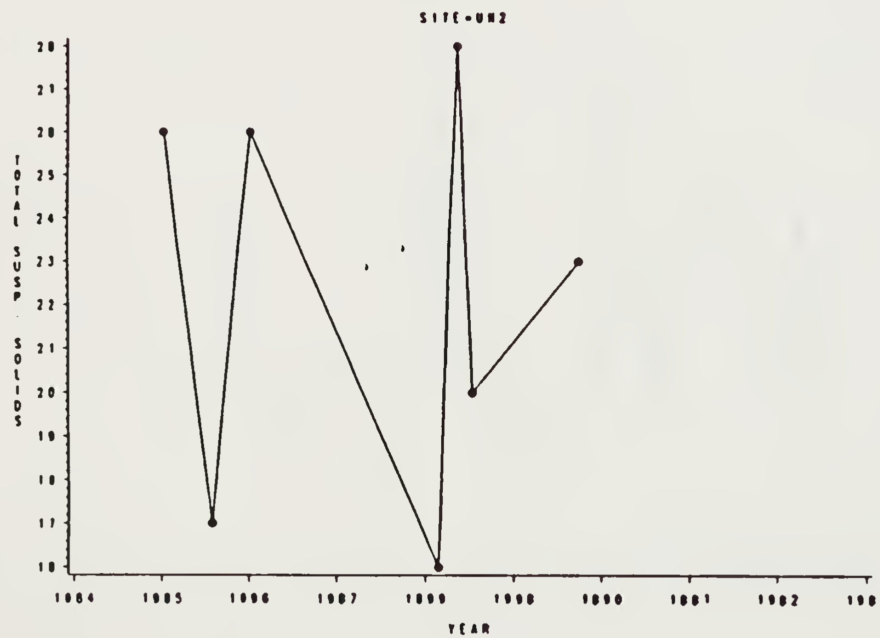

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TOTAL SUSP. SOLIDS
YEAR

SITE-UN2
TOTAL DISS SOLIDS
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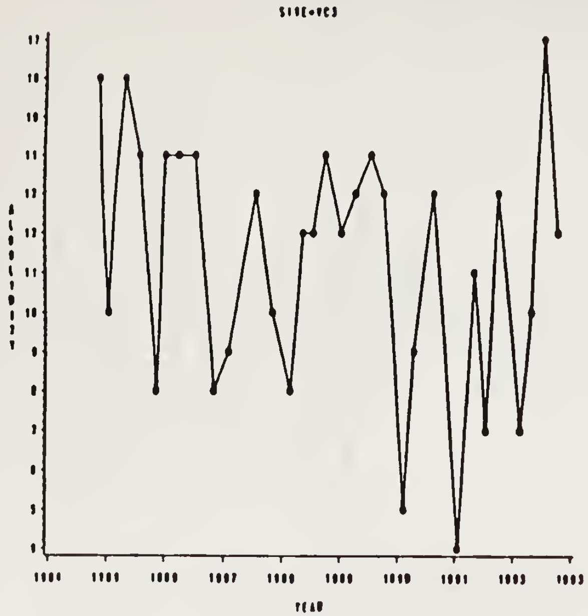
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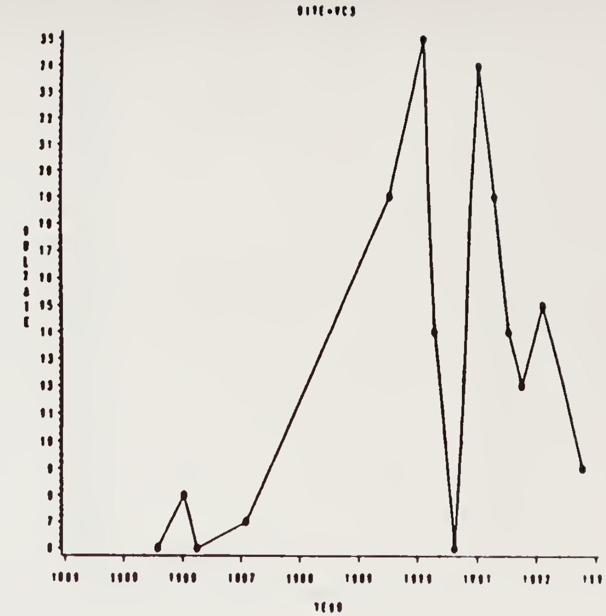
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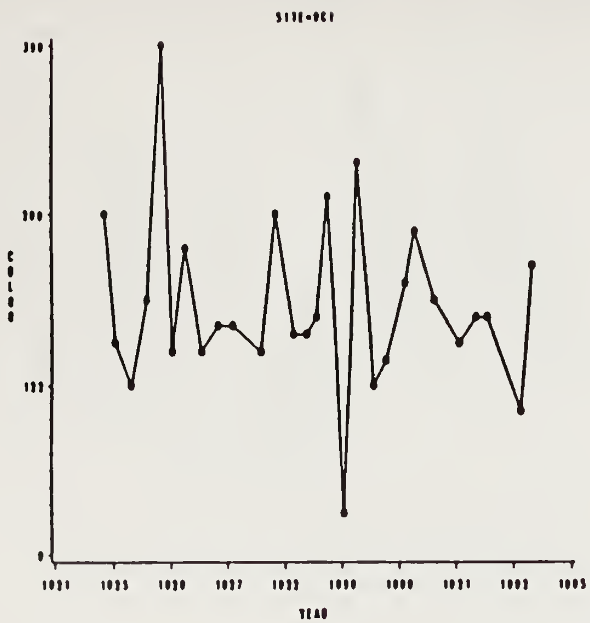
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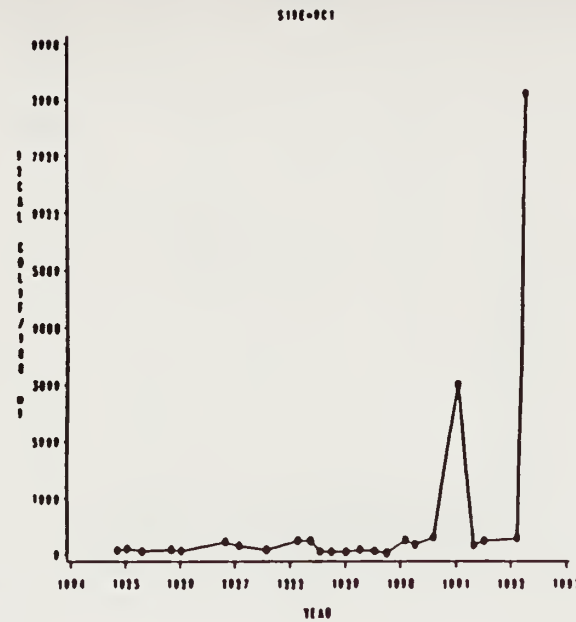
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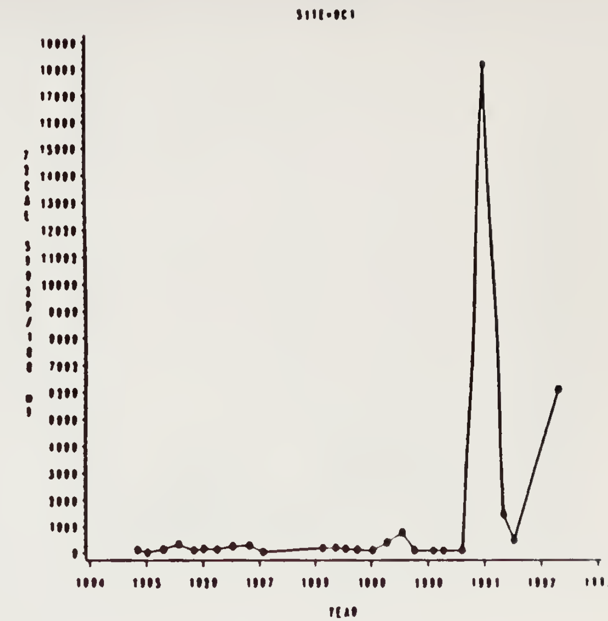
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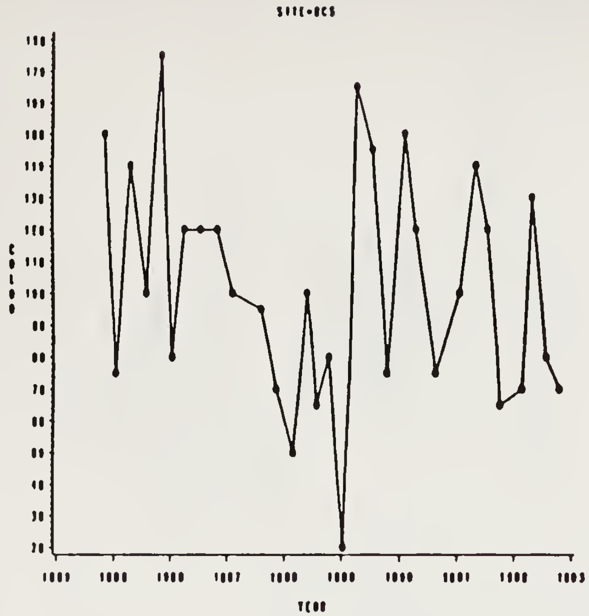

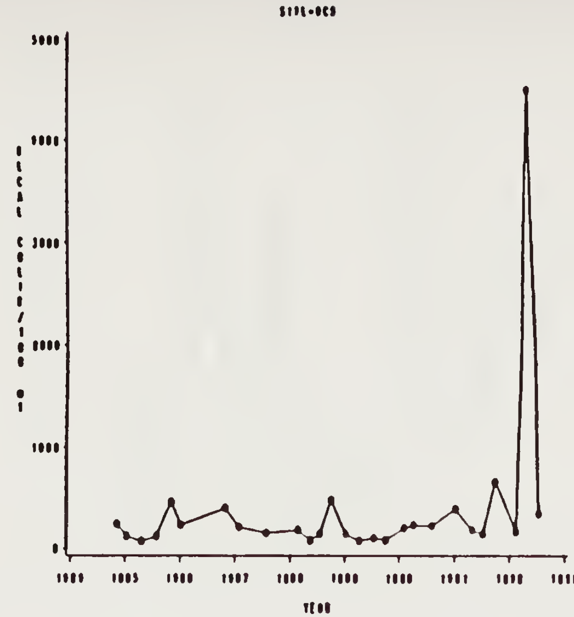

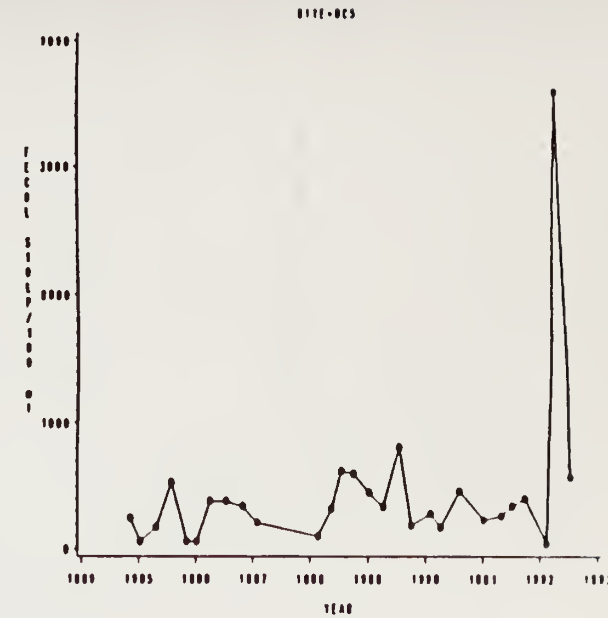

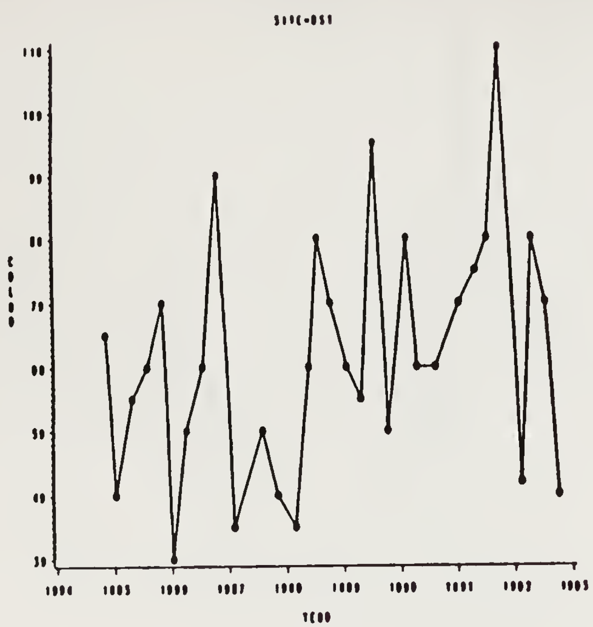

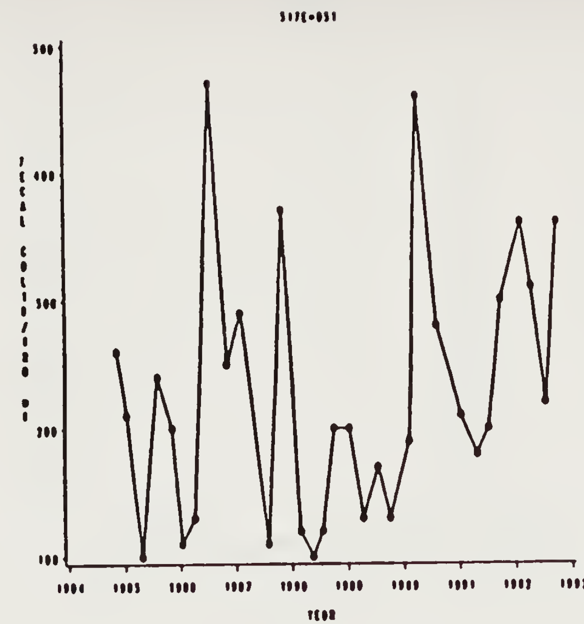

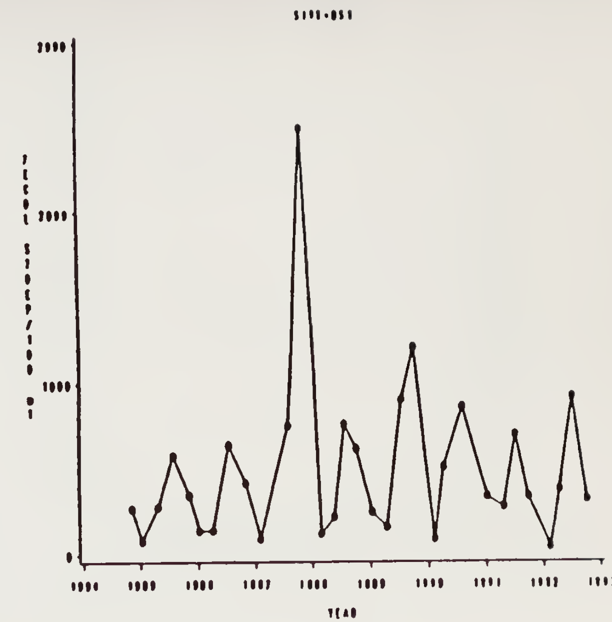

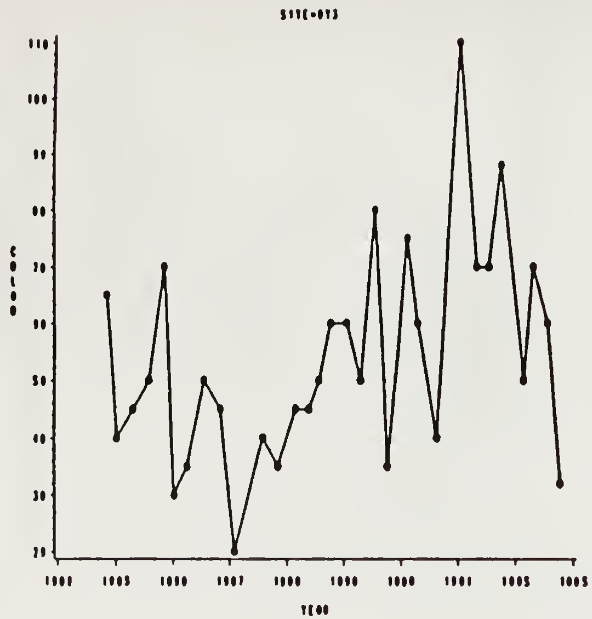

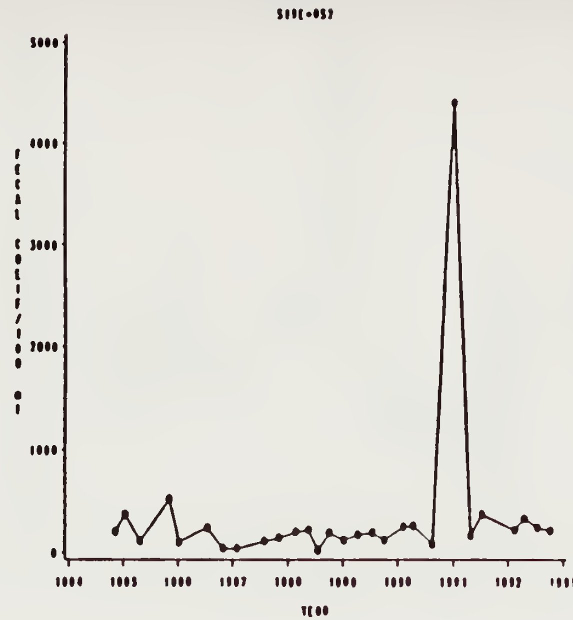

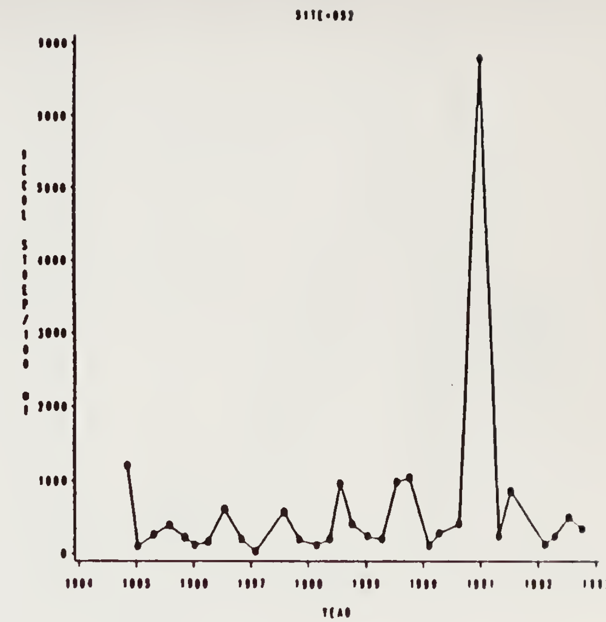

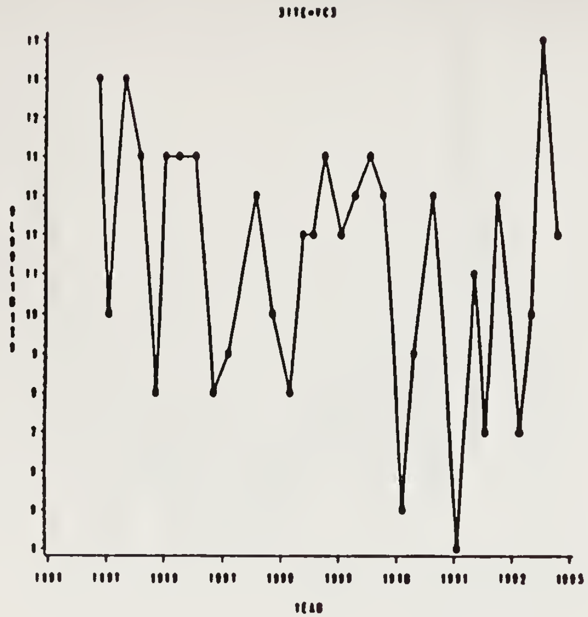

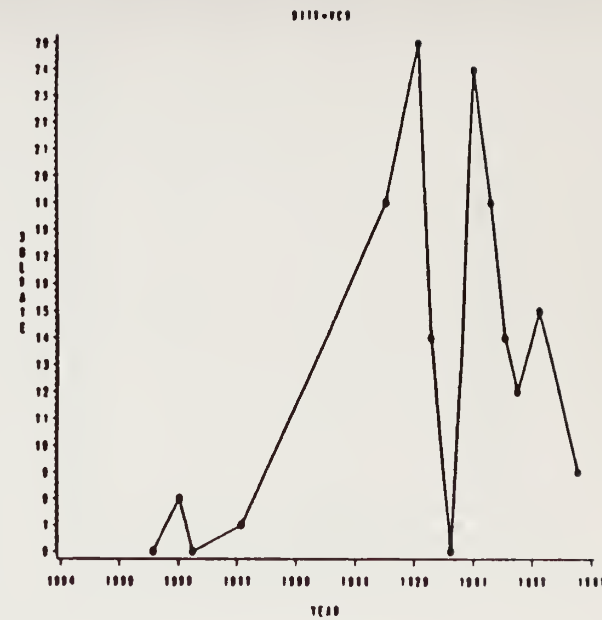

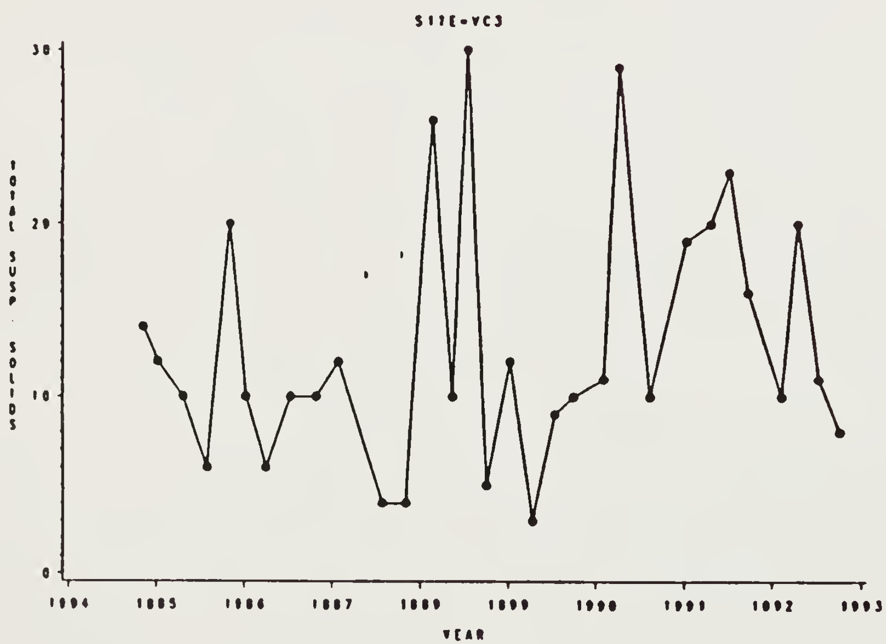
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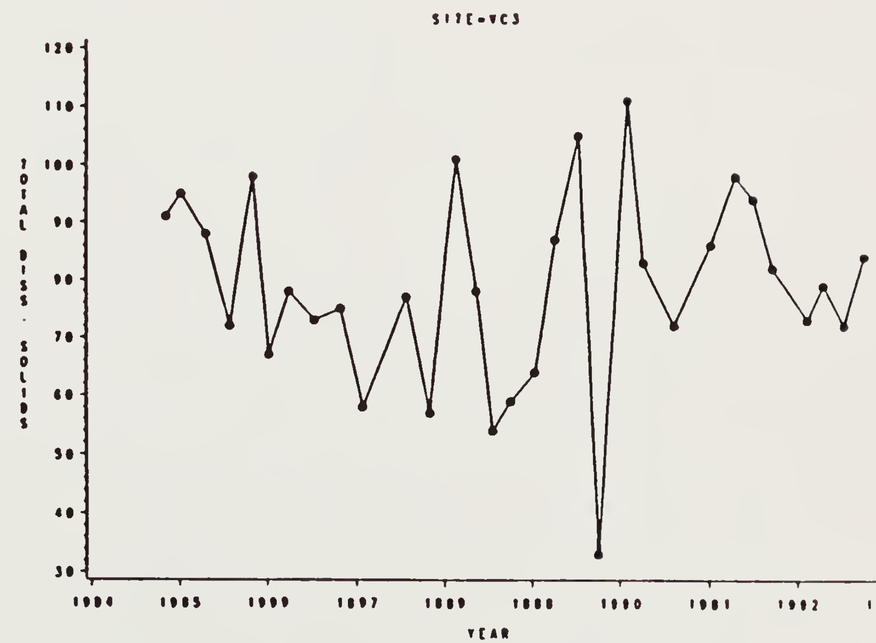
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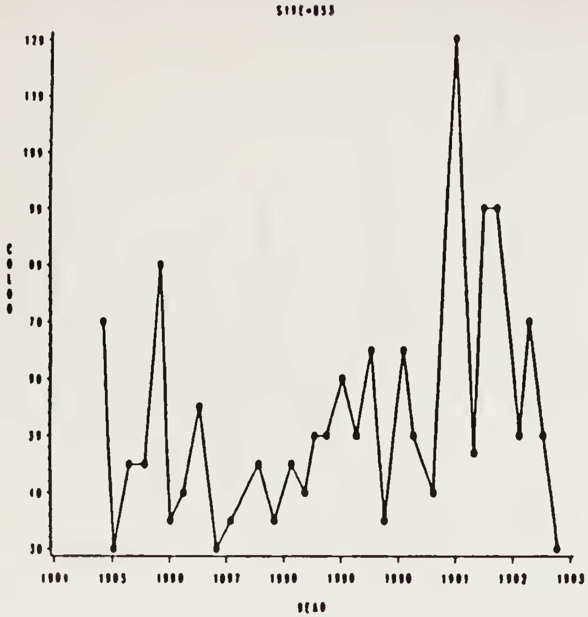

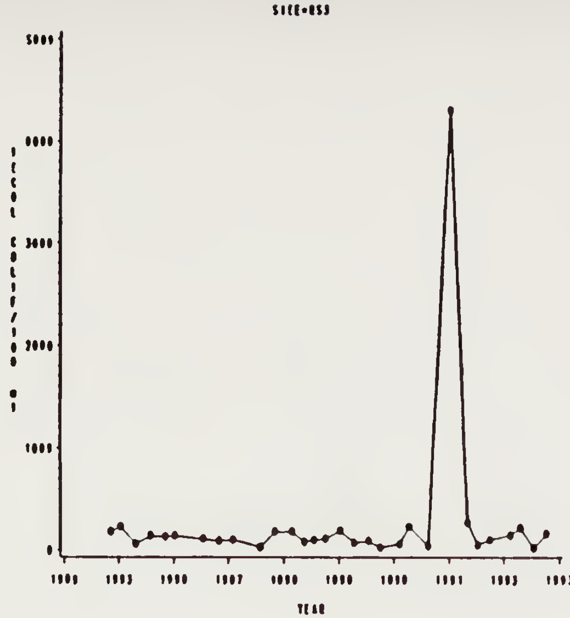

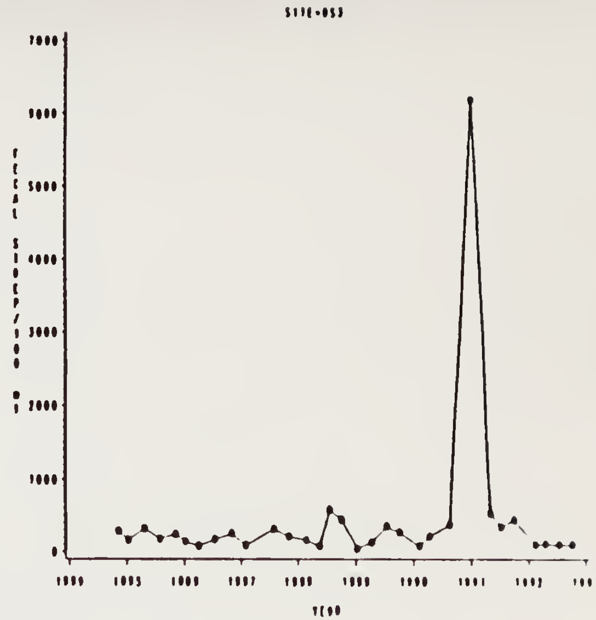

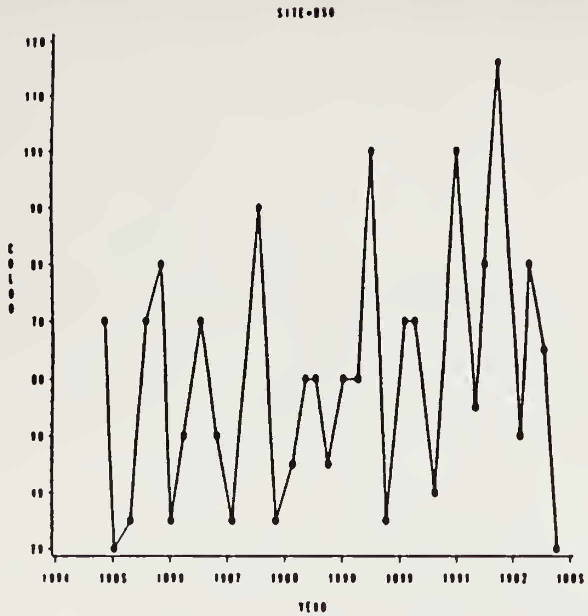

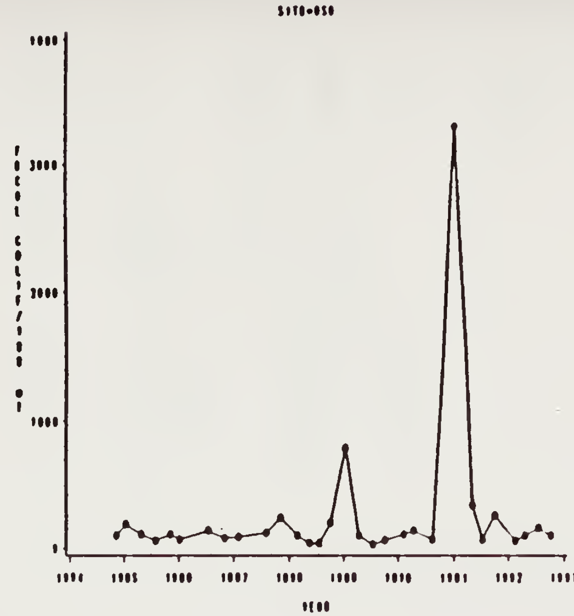

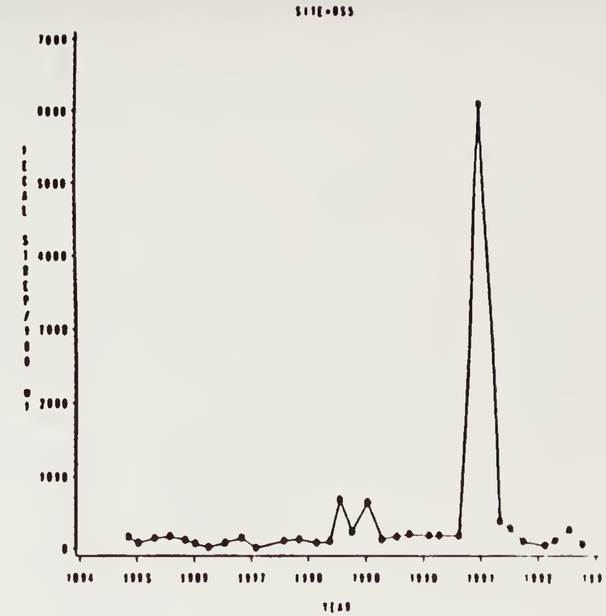

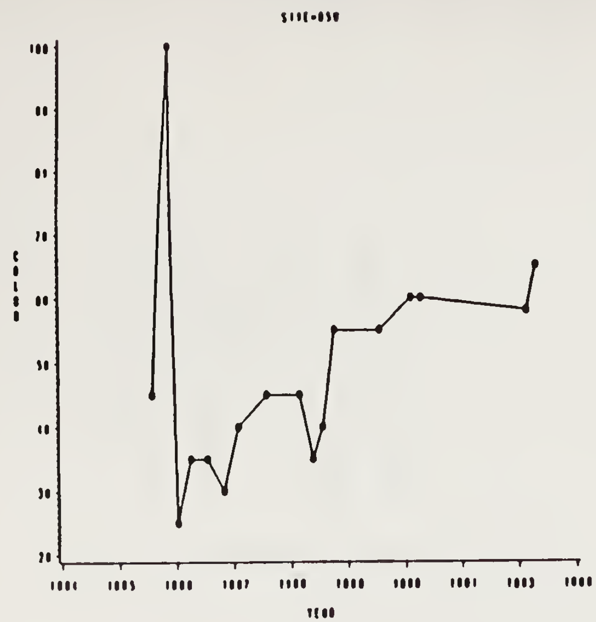

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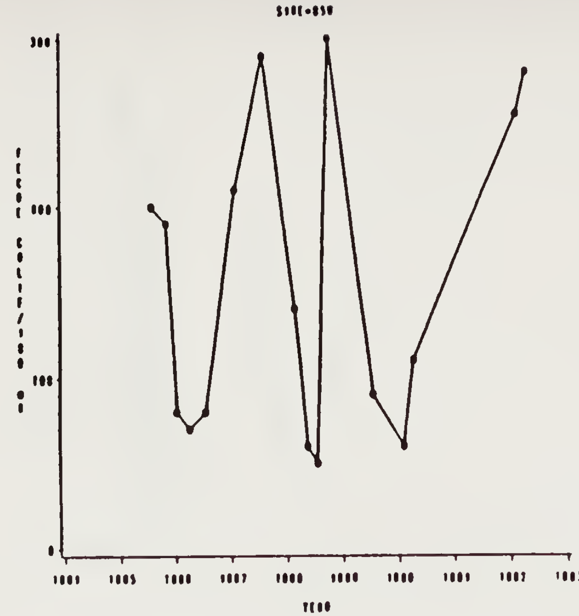

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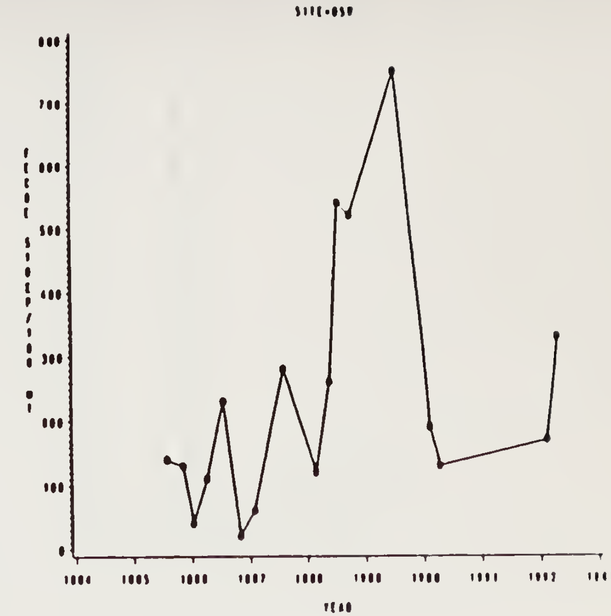

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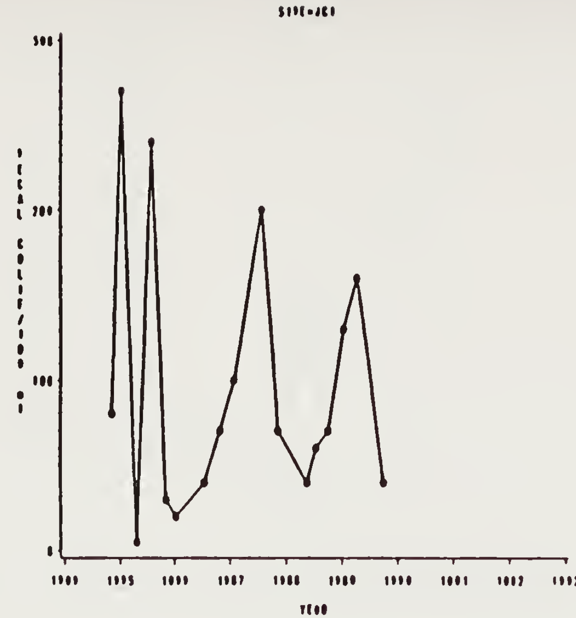

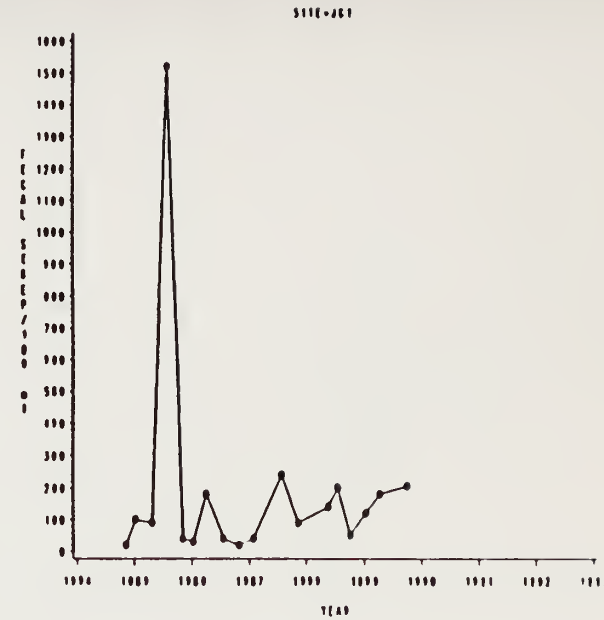

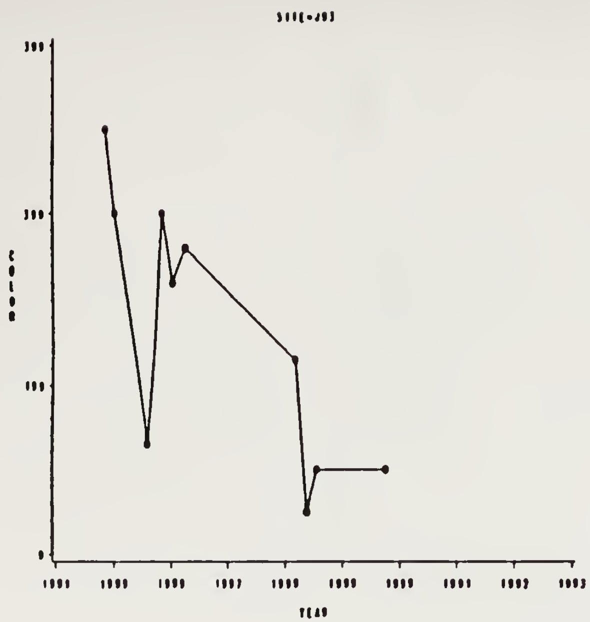

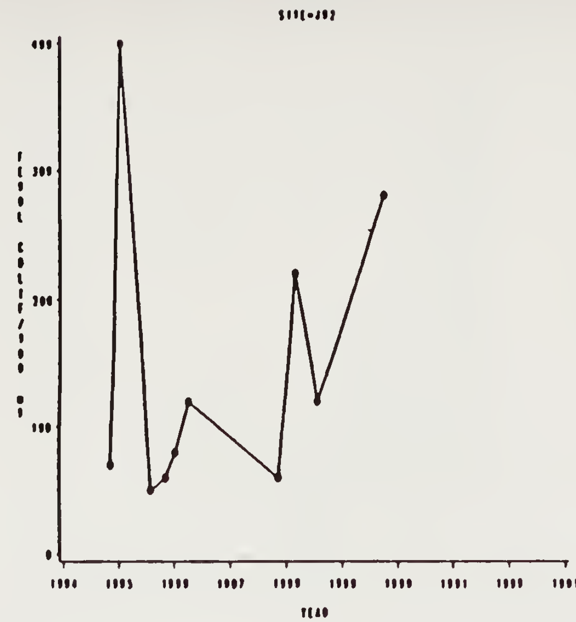

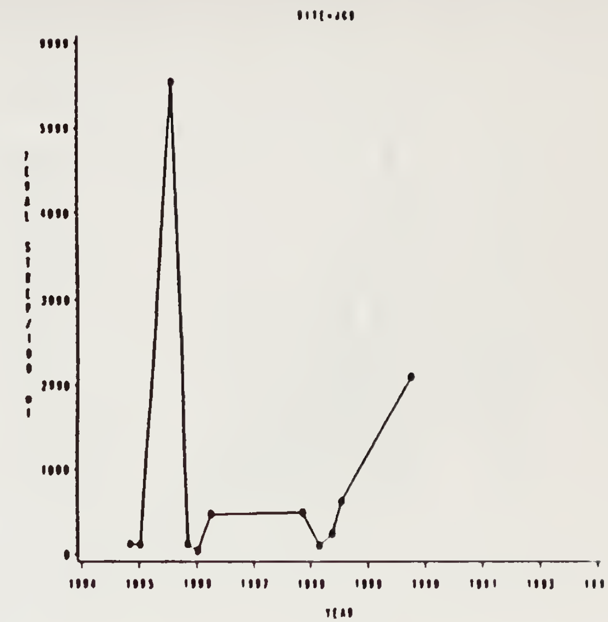

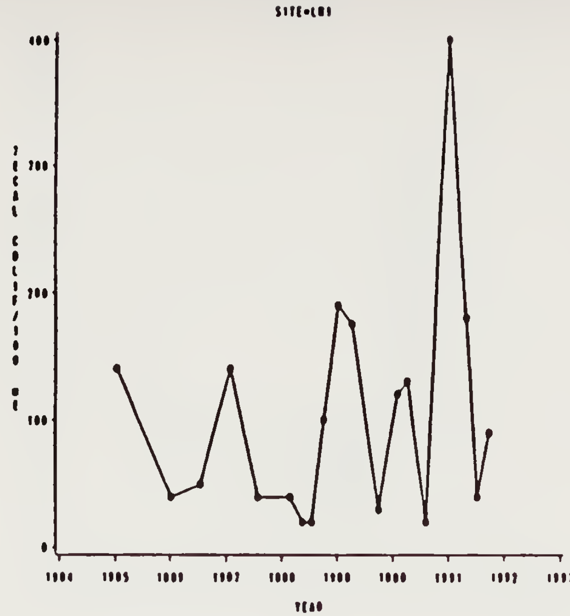

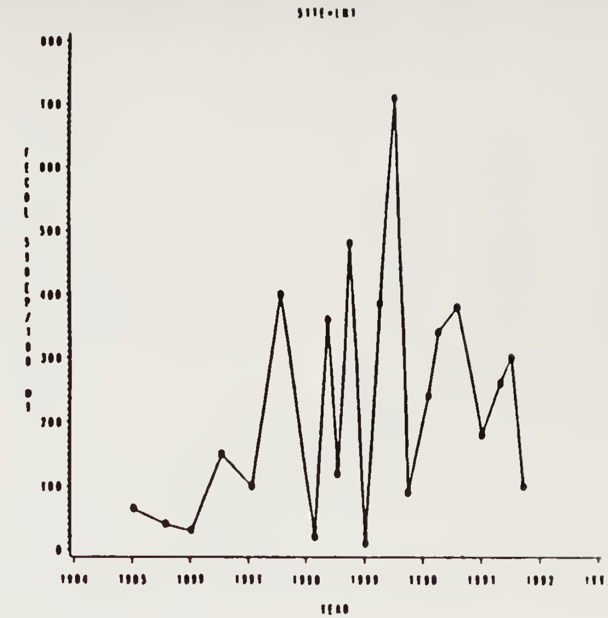

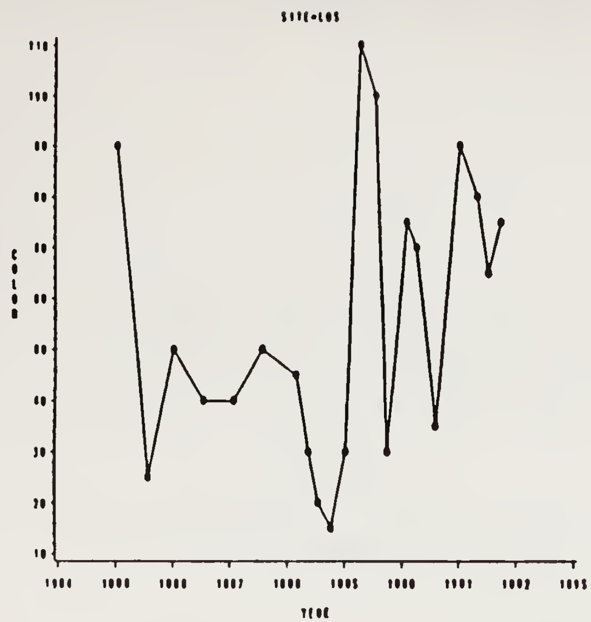

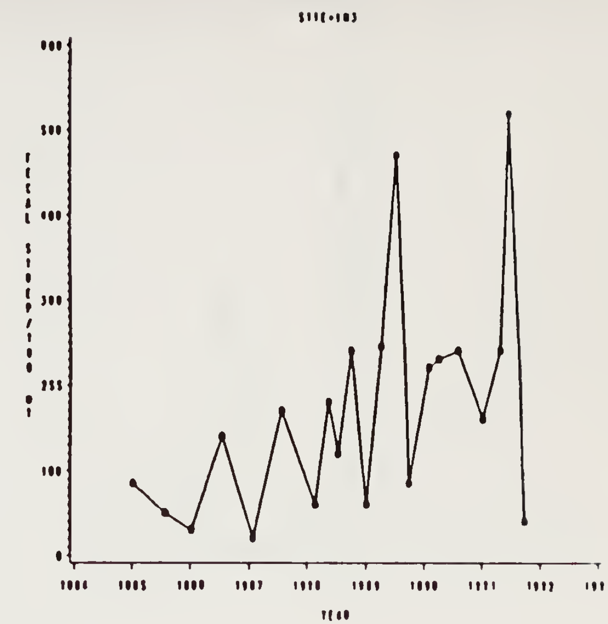

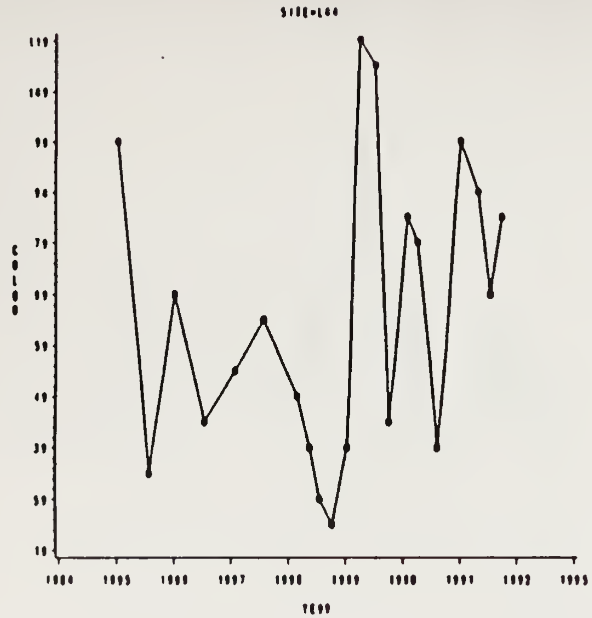
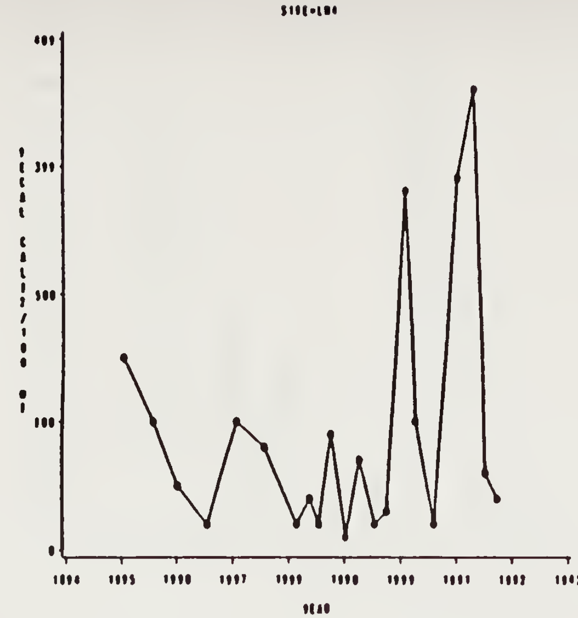
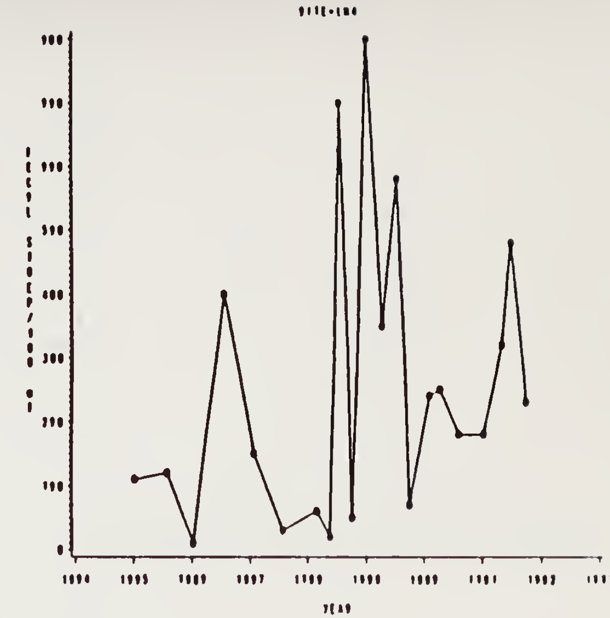

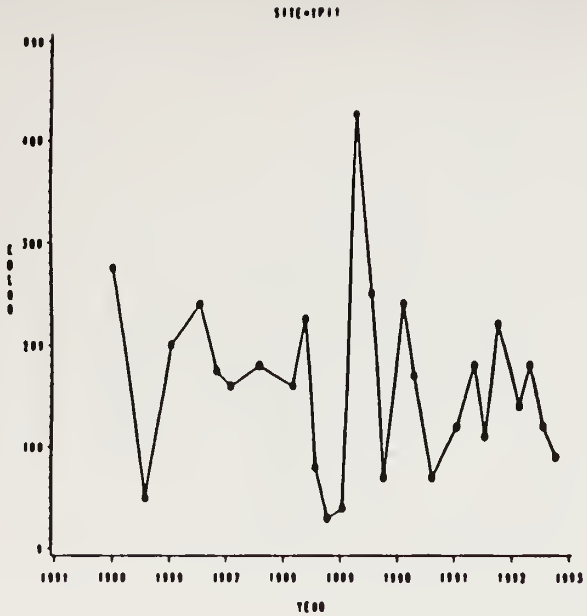

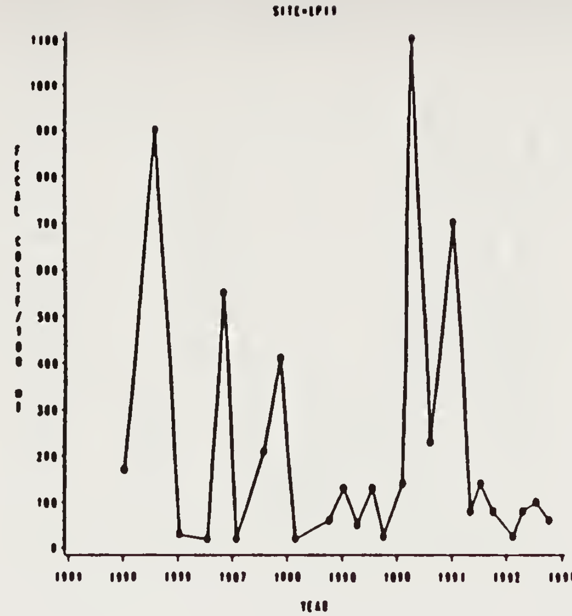

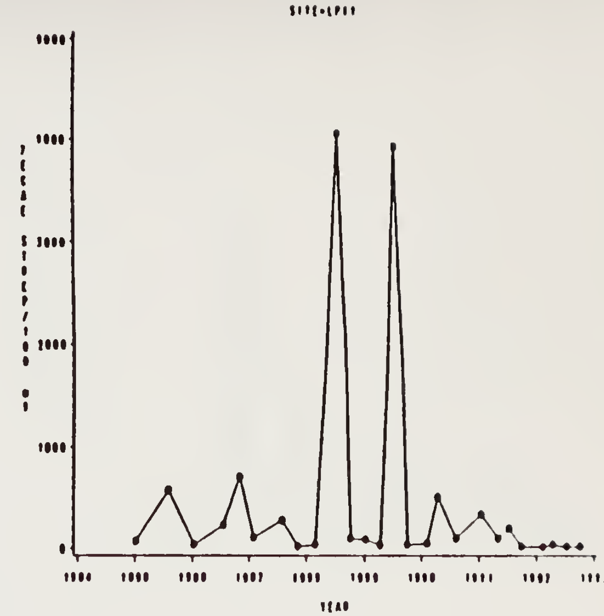

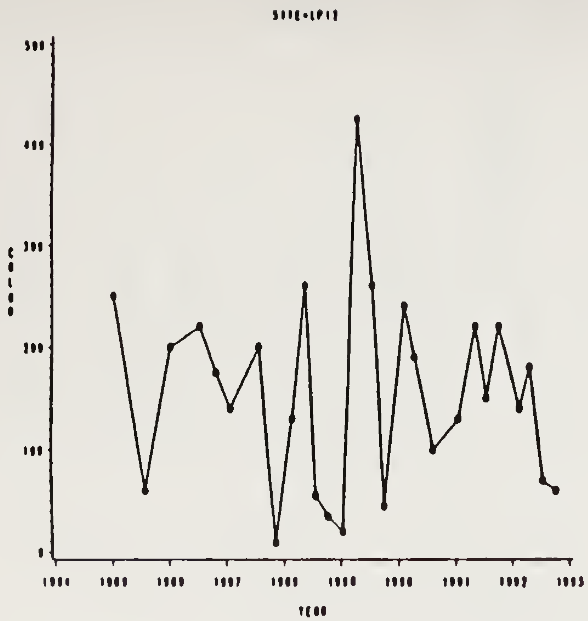
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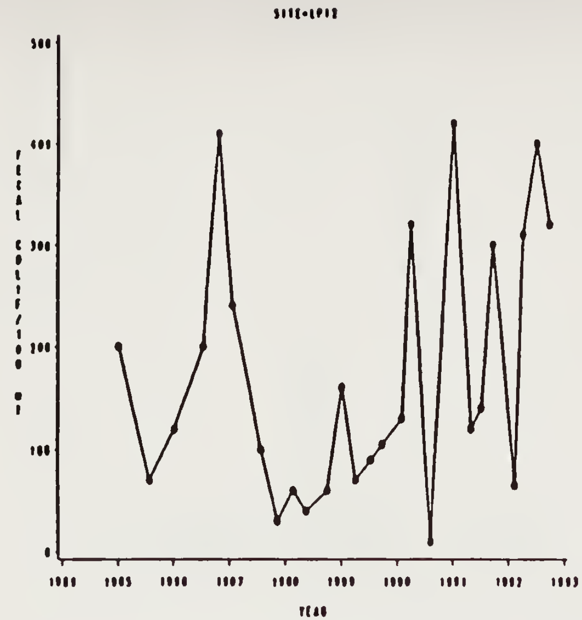
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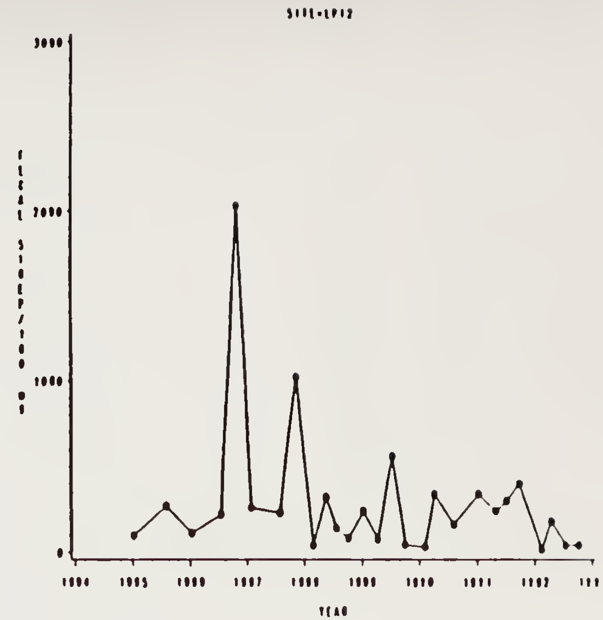
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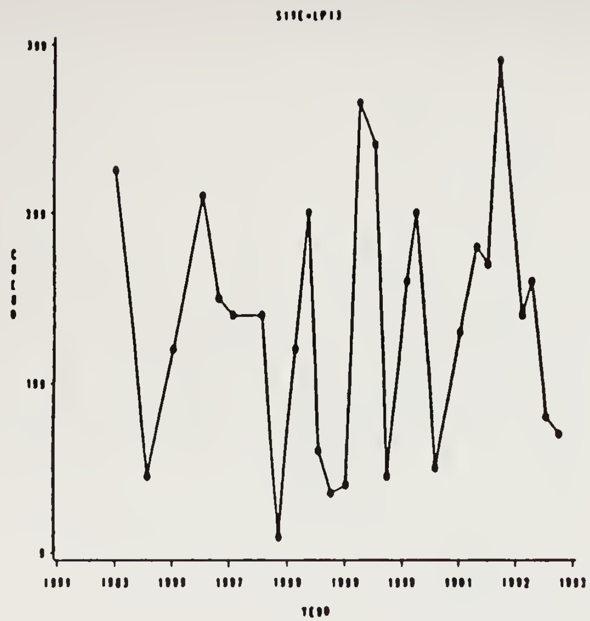

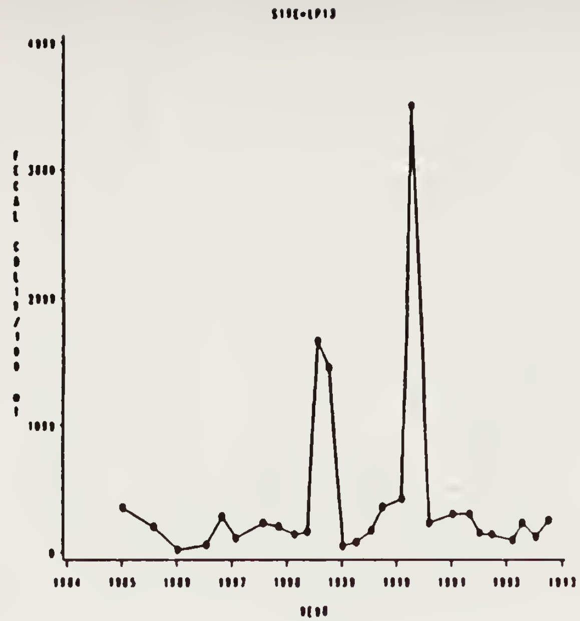

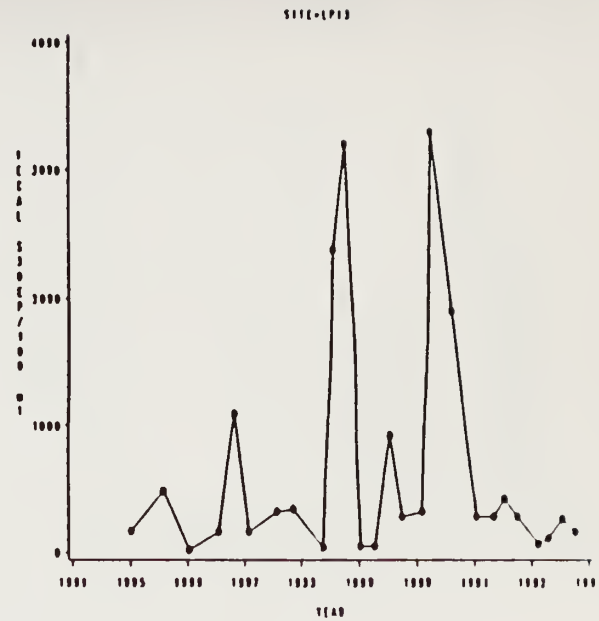

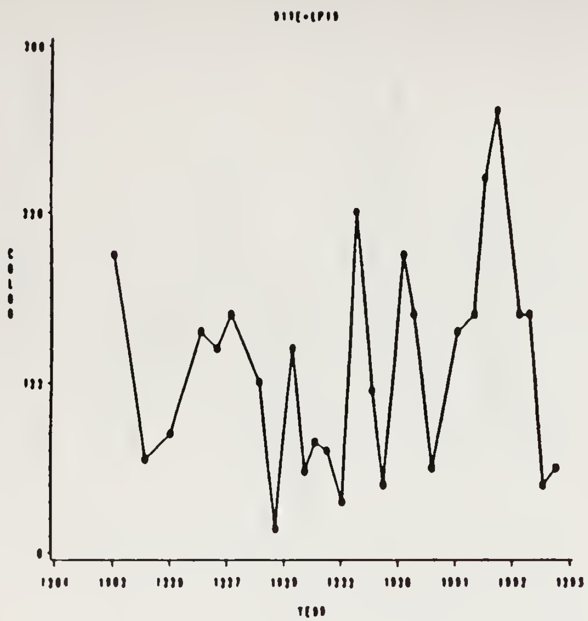

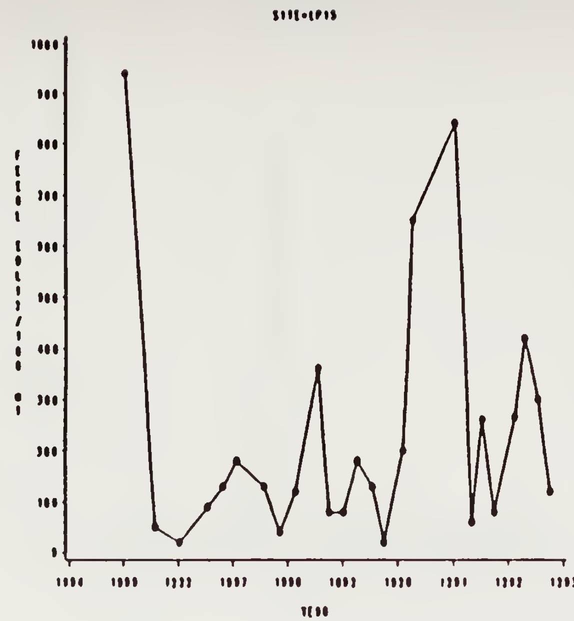

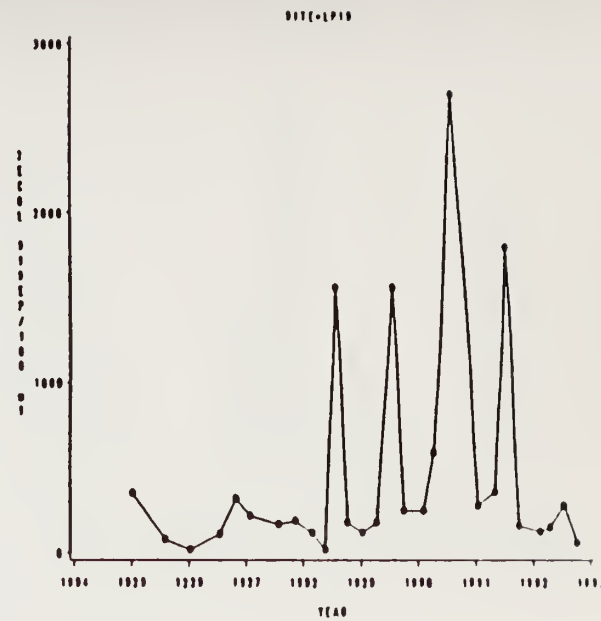
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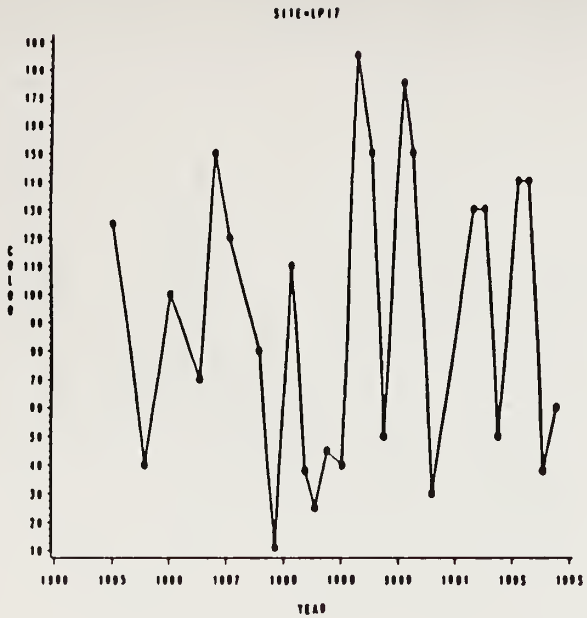

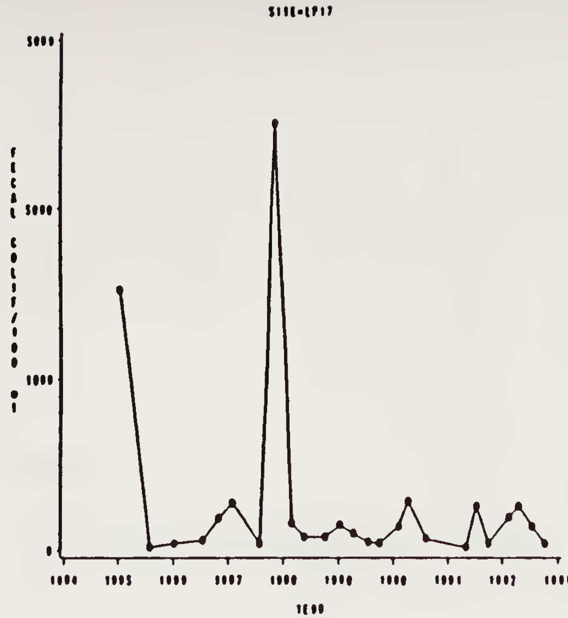

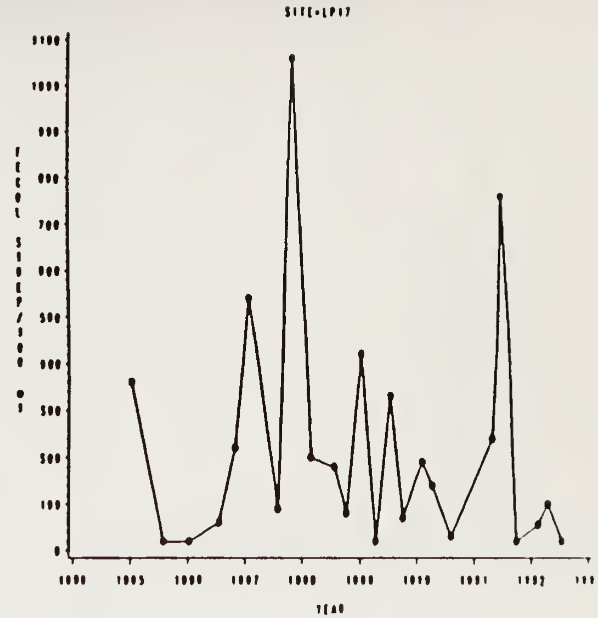

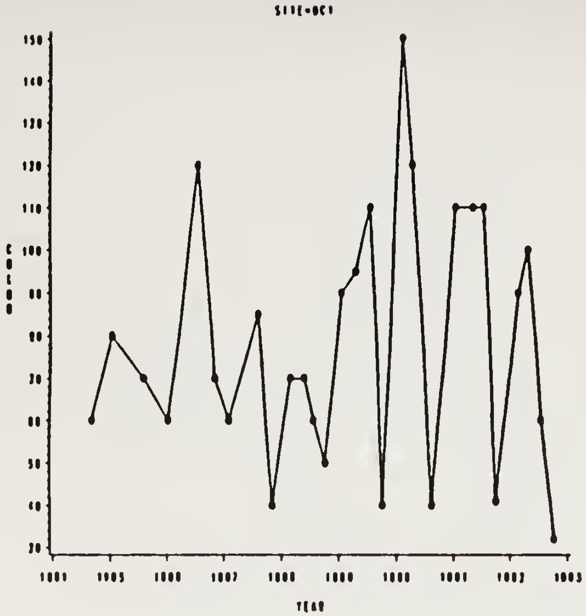

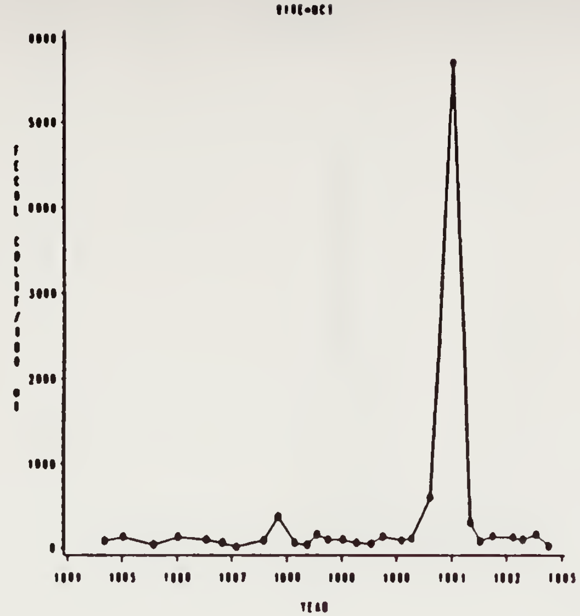

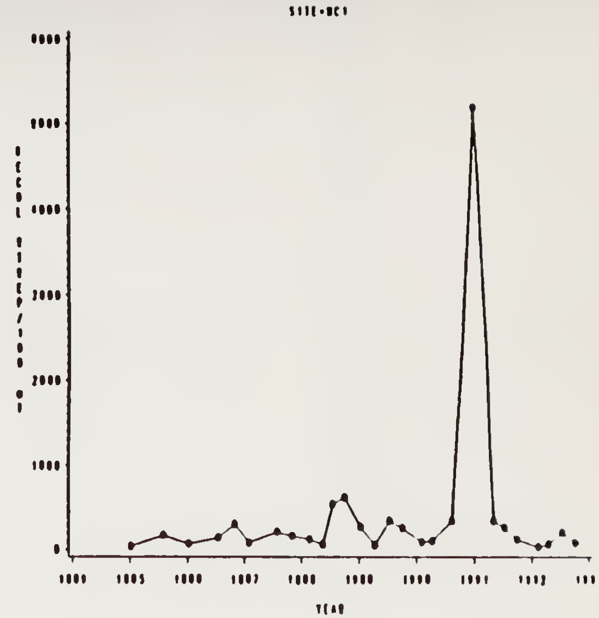

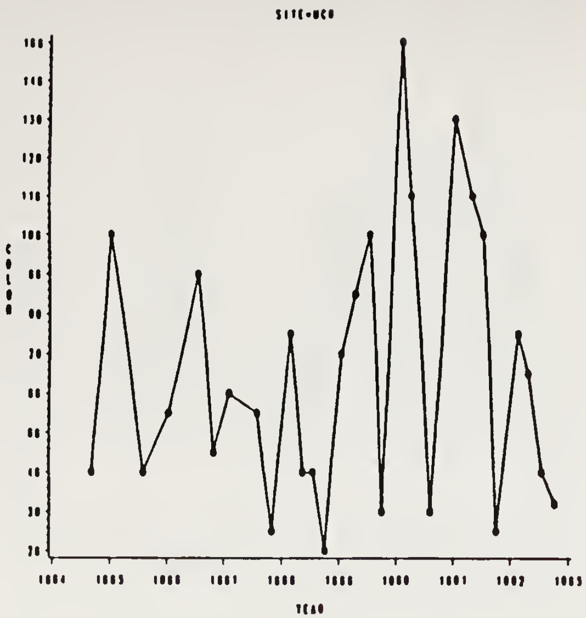

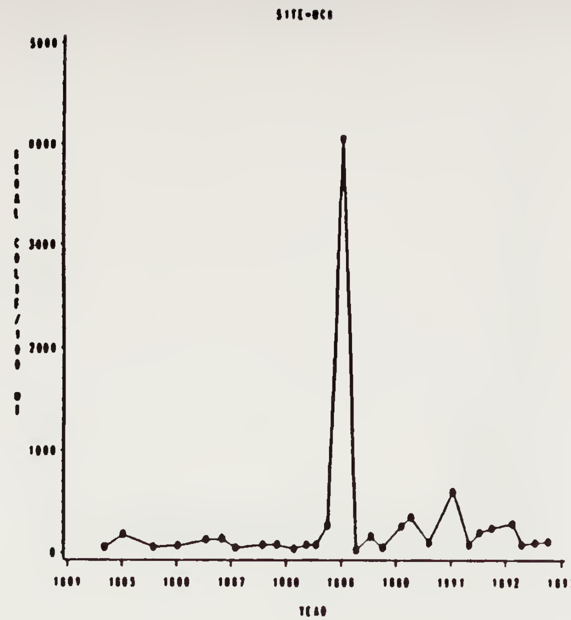

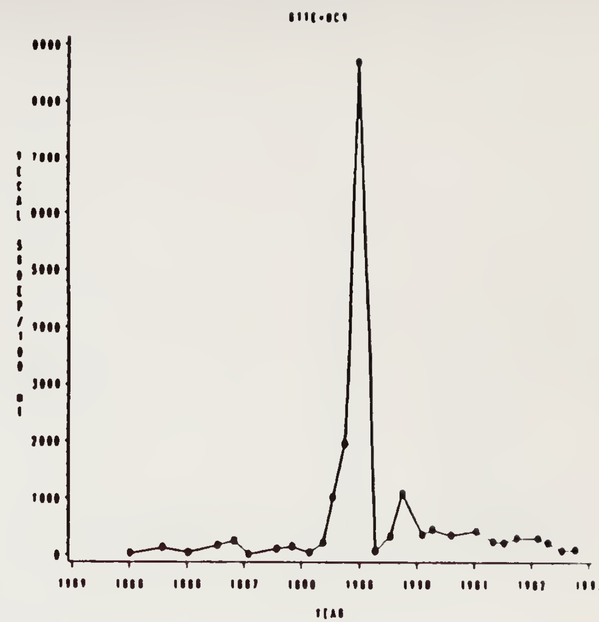

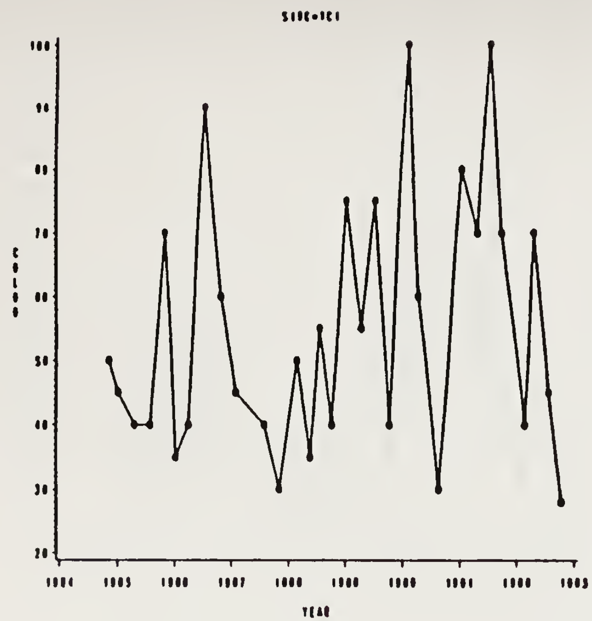
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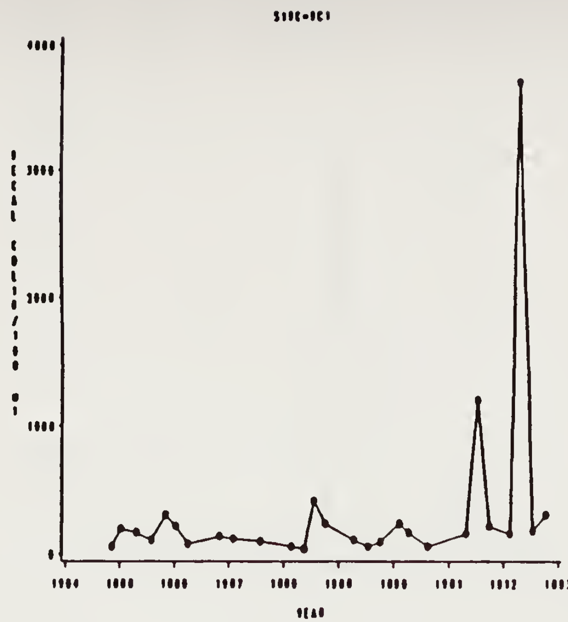
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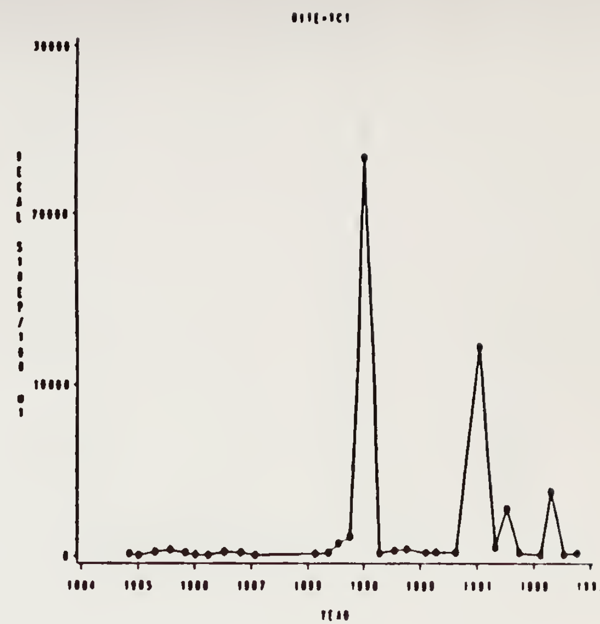
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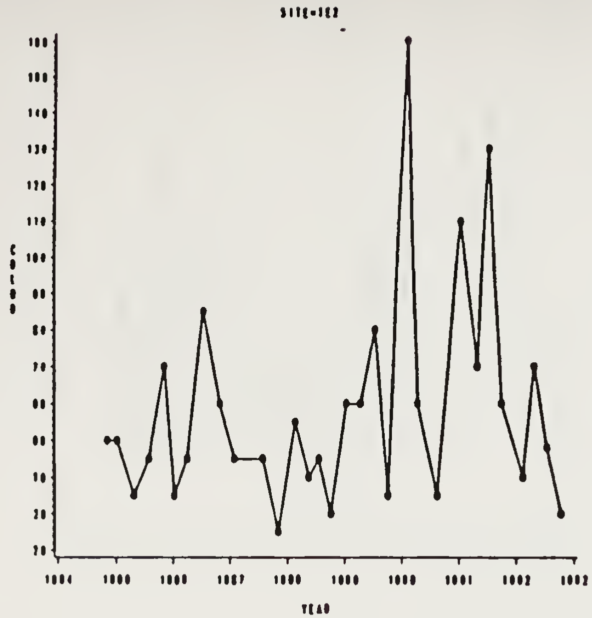

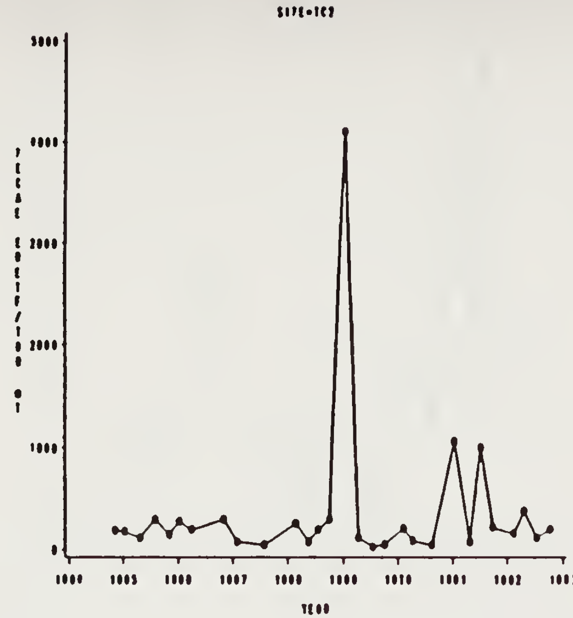

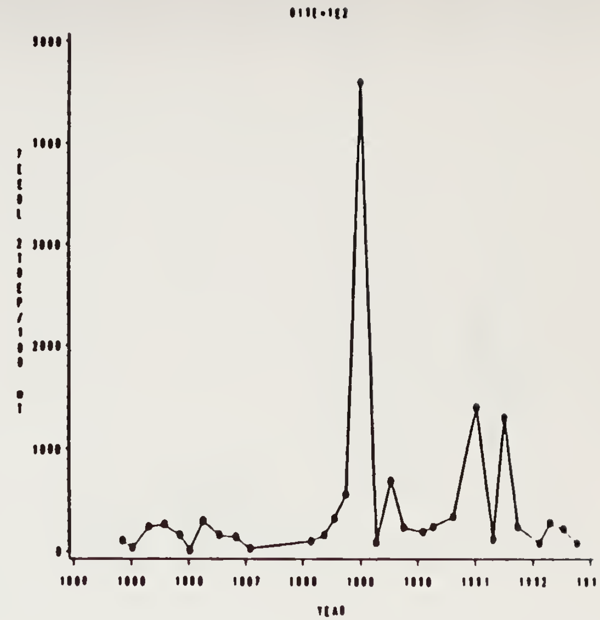

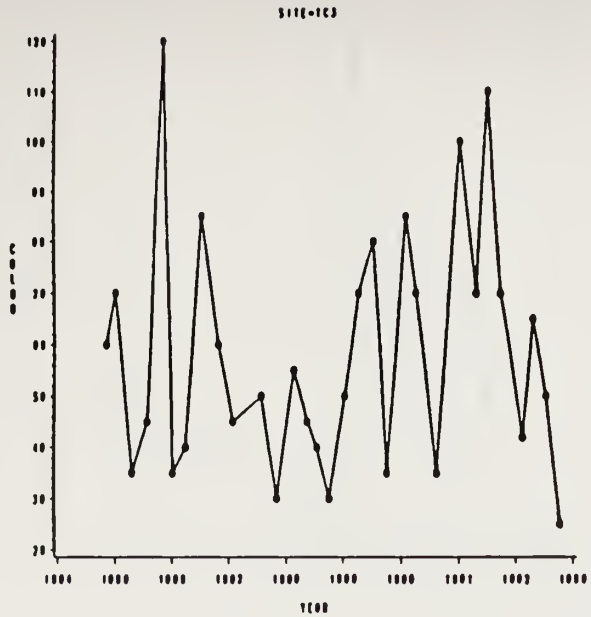

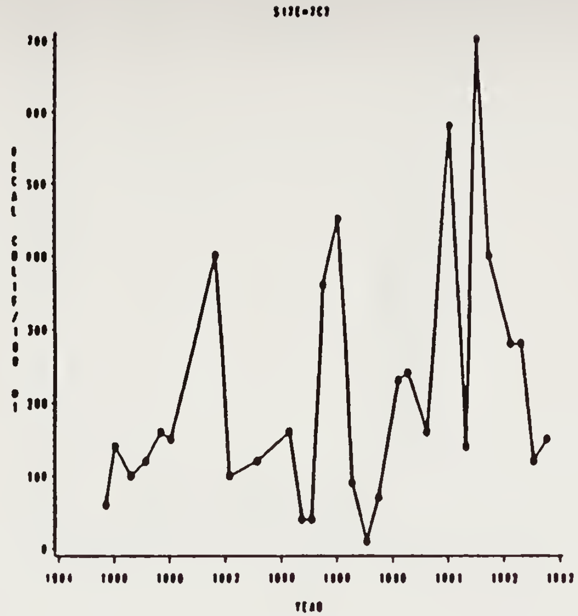

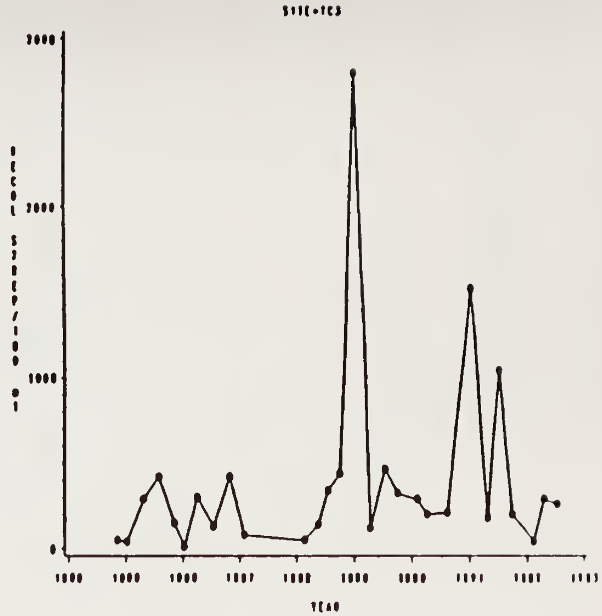

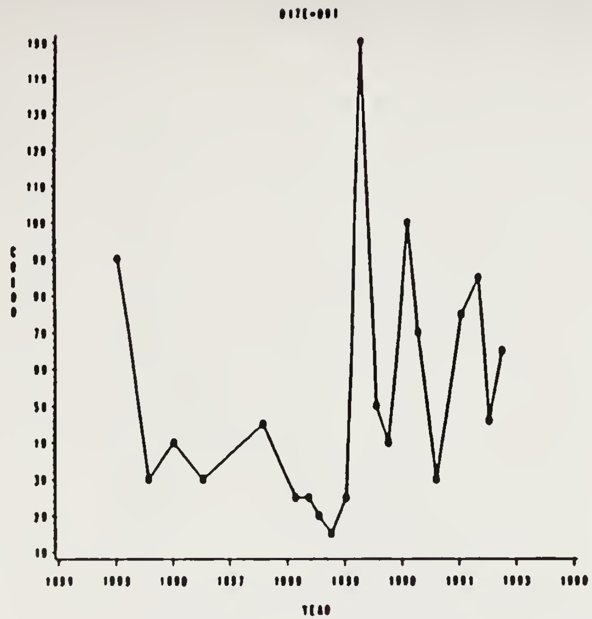
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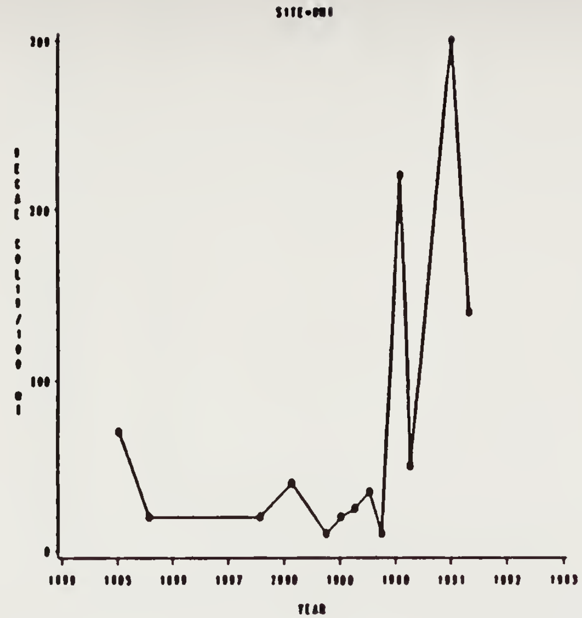
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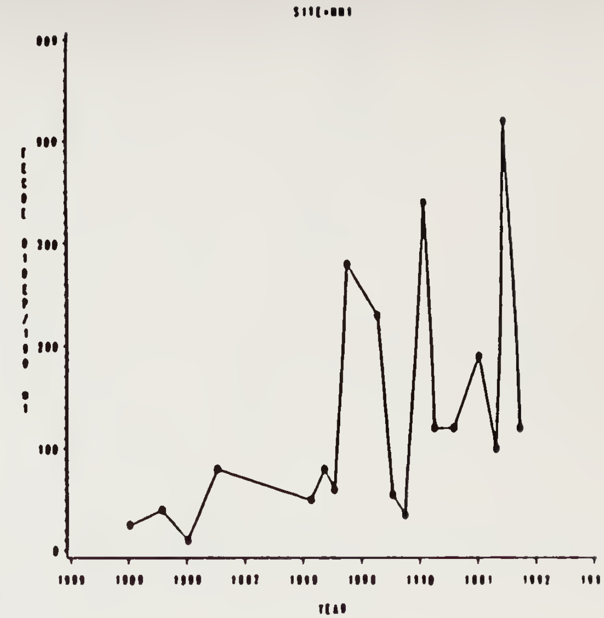
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